SITE ASSESSMENT
PHASE 4B:
SURFACE WATER
VOLUME 1 - MAIN REPORT

Prepared for
The Ontario Waste Management Corporation

Submitted By

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Consulting Engineers and Planners

October, 1987

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Consulting Engineers • Planners
Environmental Scientists

OUR FILE: 9925-31-1
YOUR FILE:

30 October 1987

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Attention: Mr. D.F. Chollak
Environmental Planner

Site Assessment - Phase 4B
Surface Water, Volume 1 -
Main Report

Dear Sirs:

We are pleased to submit the final Phase 4B Site Assessment Report on Surface Water. The report has been divided into three volumes, as follows, and presents the results of our study of baseline conditions and impact assessment.

- o Volume 1 - Main Report
- o Volume 2 - Technical Appendices
- o Volume 3 - Field and Laboratory Protocols

Volume 1 (this volume) has been subdivided into two parts. Part 1 provides a comprehensive summary of existing environmental (baseline) conditions for surface water on-site, in the site vicinity and in the Welland River. The results of the water quality and streamflow monitoring program for 1986 are provided in the context of existing criteria and regulations.

...continued

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Part 2 presents the results of our study of predicted changes to the surface water environment as a result of OWMC activities, together with proposed mitigative measures, residual impacts and recommendations for monitoring.

Volume 2 contains several technical appendices in support of Volume 1. Volume 3 details procedures for conducting water quality sampling and streamflow measurements, quality assurance requirements and detailed analytical and laboratory quality control procedures.

We look forward to assisting you with the approvals for and implementation of this very important project.

Yours truly,

M.M. DILLON LIMITED

A.K. Mitchell

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This executive summary presents highlights of the three volume report titled Site Assessment - Phase 4B, Surface Water. Volume 1 documents the existing baseline conditions, predicts changes to the surface water environment resulting from OWMC activities and presents recommendations for mitigation of adverse impacts and for a long-term monitoring program. Volume 2 contains numerous technical appendices and data summaries in support of Volume 1. The third volume details procedures used in this study for conducting water quality sampling and streamflow measurements, quality assurance requirements and detailed analytical and laboratory quality control procedures.

This report was prepared by M.M. Dillon Ltd., (Dillon) on behalf of the Ontario Waste Management Corporation (OWMC). The surface water use study and the streamflow measurements were conducted by Gartner Lee Limited (GLL). The study team is identified in Section 1.6.

PURPOSE OF THE REPORT

The purpose of this report is to document the existing (baseline) surface water environment for the preferred siting option and to predict and assess potential risks and impacts associated with development and operation of the proposed OWMC facilities. The results of the analysis were used to evaluate the suitability of the Preferred Site and to identify components of the facility design and operation which could be modified, if necessary, to reduce the risks and impacts to human health and the environment. The study also provides the basis for a long-term monitoring program to ensure the effectiveness of the facility design and operations.

SCOPE AND METHODS

The Phase 4B surface water program includes study of hydrometeorology, hydrology, hydraulics, surface water use, erosion and sedimentation and surface water chemistry. The investigations for each discipline generally included:

- development of a detailed work plan and protocols for field studies;
- field studies including recording of streamflows and water levels, water quality sampling, topographic survey for vertical control and interviewing of local residents and agency staff familiar with the study area;
- laboratory testing; and
- data compilation, analysis, interpretation and reporting.

A list of the major project elements is provided in Section 1.3. Detailed descriptions of the study assumptions and methods are contained in Chapter 2 (for baseline conditions analysis) and in Chapter 5 (for impact prediction), together with the supporting appendices, as referenced.

STATUS OF DATA

Data used in the surface water studies were obtained from two principal sources:

- published literature/data on precipitation, streamflow and water quality;

- field data collected during the course of the study including streamflow in local watercourses, water levels and surface water quality.

The protocols used for both field sampling/monitoring and analytical and laboratory quality control procedures are outlined in Volume 3. A rigorous quality assurance/quality control (QA/QC) system was implemented to ensure that analytical water quality obtained was accurate, consistent and well documented.

The data base collected during the Phase 4B surface water studies is considered acceptable for the intended purpose, namely the definition of baseline conditions and assessments of risks and impacts for the proposed facilities.

FINDINGS

WATER QUANTITY-BASELINE

All surface runoff from the Preferred Site drains to the Welland River via three small intermittent watercourses. The Welland River is characterized by a very mild gradient leading to a sluggish river system, with a rather slow hydrologic response and considerable flood plain areas. However, the Welland River floodplain does not extend to the Preferred Site.

Water levels in the Welland River in the vicinity of the Preferred Site are controlled by river hydrology/hydraulics and by Ontario Hydro operations downstream. During periods of zero or near zero flow in the Welland River, Ontario Hydro's operations maintain sufficient backwater to ensure an adequate, continuous supply of water for OWMC operations.

The Preferred Site is characterized by very little topographic relief and is generally poorly drained. Relief is provided by small ridges and swales. While surface drainage is generally in a north to south direction, the overland flow path is frequently discontinuous resulting in local ponding during wet weather and/or snowmelt. Surface runoff from the site is further retarded by low capacity outlet culverts, leading to on-site ponding upstream of these culverts, for significant runoff events.

Hydrologic computer modelling of the Preferred Site was used to develop a composite site hydrograph for storms of varying magnitude. The existing condition peak flow from the site, for the 1:100 year storm, was estimated at just over 2 m^3/s, for all outlets combined.

Hydrologic/hydraulic analysis of Sucker Creek indicated that back-up of floodwaters onto the site from Sucker Creek may occur under extreme events. The points of entry onto the site would be two culverts under Highway 20, west of Silverdale Road.

Surface water use on-site and in the site vicinity is limited by the availability and quality of supply. Local watercourses in close proximity to the site flow intermittently and are only infrequently available as a source of water. Three properties downstream of the site, along 9C Creek, occasionally use surface water for livestock watering.

WATER QUALITY-BASELINE

Surface water quality at the Preferred Site is typical of surface water found in an agricultural environment. The Welland River, in spite of the appearance, is generally of good quality. It is not surprising that it fails to meet acceptability criteria in the areas of nutrient loading and bacteriological health. These problems are confounded by low flows in the river during cool weather leading to exceedences of criteria for nutrient-related material normally assimilated in warmer faster moving water. The criteria for acceptability were generally those for drinking water; there occurred no consistently persistent water quality indicator concentration that would limit the use of this water given that appropriate conventional water treatment was applied.

Local streams surveyed, particularly in periods of high flow exhibited much poorer water quality reflecting their proximity to the source of inputs of nutrients and bacteria. Trace metals and other inorganic contaminants were found in these local streams. Again, this reflects fresh runoff from agricultural activities as well as other human activities in the area.

Comprehensive scans for priority organic pollutants were carried out. Some indications of contamination from petroleum products (gasoline origins) and from plasticizers were found. However, these indicators may be artifacts of the whole sampling and analysis procedure. This is not an unusual finding when trace concentrations of these materials are sought in a real world (including the sampling environment through to the laboratory). These trace contaminant indicators are not considered a concern because of the way in which the occurrences presented but they are noted for follow-up in continued monitoring.

Some pesticide occurrences were noted in the surface water, noticeably the herbicide atrazine. This is a common finding in agricultural areas. This herbicide is of low toxicity, non-persisent and not accumulative.

WATER QUANTITY - IMPACTS

The post-facility hydrologic assessment was based on a number of surface drainage management features, as defined by the engineering consultant (Monenco), and on a practical landfill surface concept developed by Dillon, in cooperation with the hydrogeological consultant (Gartner Lee) and the engineering consultant. The surface drainage management features, adopted for the facility design, and the landfill surface drainage concept are outlined in Sections 2.2.1 and 4.4 respectively.

The post-facility hydrologic analysis considered two time frames, reflecting changes in operation of the surface drainage system for the Central Operating Area (COA). These are:

- During Facility Operation, when all runoff within the COA is retained and tested prior to release (i.e. runoff from the COA will not contribute to peak flows from the site).

- After Facility Closure, when the COA facilities are removed from the site and the area is regraded/revegetated and will drain by gravity through the adjacent landfill surface drainage system (i.e. runoff from the COA will contribute to peak flows from the site).

Under worst case conditions (post-closure), the peak flow for the 1:100 year storm was estimated at approximately 11.8 m^3/s, almost six times greater than that estimated for existing conditions. This results from improved on-site surface drainage efficiency and elimination of the existing depression storage. Left uncontrolled, the increase in peak flows would result in significant flooding of lands downstream of the site, together with associated increases in flow velocity and potential for streambed erosion.

The impact of increased flows and runoff volume from the site is much reduced for the Welland River, because of the much larger size of its watershed and the relative conveyance capacity of the river channel. The increased volume of runoff for the 1:100 year storm was estimated to increase flood levels in the Welland by a maximum of 0.012 m (0.5 in.).

The opportunity for use of surface water from intermittent streams, downstream of the site, will be reduced by the proposed diversion of site runoff directly to the Welland River, via the Heaslip Road storm sewer. In particular, three properties along 9C Creek will be affected. The impact of reducing the available surface water supply is not considered serious because of the intermittent nature of the watercourse. Furthermore, at least two of the affected properties will benefit from reduction of local flooding along 9C Creek.

WATER QUALITY - IMPACTS

Nuisance impacts such as erosion and downstream sedimentation can be significant for a major construction project. Rates of erosion were estimated for a number of land use conditions and construction activities. The results are presented in Table 6.3.

Soil loss rates under existing conditions and after closure of the facility are expected to be similar and should be very low (assuming full revegetation). Much higher erosion rates were predicted with bare soils, with the highest rates associated with unvegetated slopes of berms, ditches and stockpiles.

Impacts associated with unchecked erosion include:

- water quality impairment affecting surface water uses and biological resources
- loss of cover over completed portions of the landfill;
- frequent maintenance on-site;
- loss of capacity within internal and perimeter ditches;
- loss of capacity within downstream receiving waters;
- reduced culvert and channel capacity due to silting
- increased flooding.

Under a normal river regime, proposed water takings by OWMC, particularly during periods of zero or near zero flow, could be expected to reduce base flows, lower river levels and impair river water quality. However, Ontario Hydro operations on the lower Welland River ensure an adequate depth of water at all times. Even during periods of no flow in the Welland River, water withdrawn by OWMC will be continuously replenished from downstream. No measurable effect on river water levels were predicted. Similarly, river water quality should not be impaired by OWMC water taking although long-term monitoring that comprehensively characterizes water quality and water quality changes should be included in the operational procedures of the facility.

Specific management features are proposed for the OWMC facility, which will minimize the opportunity for release of contaminants to the surface water environment (Section 6.2.3). Nevertheless, a very small risk does exist for the accidental discharge of contaminated storm runoff from the COA into the Welland River. Appropriate contingency measures have been proposed to address this risk and should be considered in OWMC's emergency response plan.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of study findings described above, the following mitigation measures are recommended to minimize impacts of the proposed OWMC facility:

- Site runoff management
  - a network of swales, berms and perimeter ditches will be used to convey runoff to a single outlet at the south end of the site;
  - both the central operating area and landfill area will be bermed and runoff from each area managed separately;
  - external areas which now drain through the site will be intercepted and routed around the site perimeter using ditches, storm sewers and/or berms.
- Peak flow reduction
  - all runoff which originates on the landfill site will be directed to a storm detention pond at the south end of the site. This pond will reduce post-development flows to near pre-development levels.

°	Outlet	- the only outlet for storm water leaving the site will be a storm sewer at the south end. This storm sewer will drain the storm detention pond, run along Heaslip Road and discharge to the Welland River approximately 2 km to the south.
°	Flood susceptibility from off-site	- potential for minor site flooding under very rare events (Hurricane Hazel) has been identified due to back-up of flood waters along Sucker Creek. The proposed perimeter berm and ditching will eliminate the potential for flood waters to enter the site from Sucker Creek.
°	Water use	- if necessary, the impact on downstream water use of diverting site runoff from 9C Creek to the proposed Heaslip Road storm sewer can be mitigated by providing users with water from OWMC's raw water line along Heaslip Road.
°	Erosion	- implementation of a comprehensive erosion control plan is necessary to minimize transport and deposition of sediment downstream from the site. The clay soils characteristic of the area are difficult to settle out once they are suspended in water. Therefore, erosion control at the source is essential. This includes minimizing the length of time that bare soils are exposed, revegetating as quickly as possible after grading, vegetative buffer strips, straw bale dykes, minimizing overland flow and ditch slopes, and sediment traps or check dams in perimeter ditches.
°	Accidental release of contaminated surface water	- to mitigate the potential impacts of very infrequent (if any) accidental release of contaminated surface water, the following

contingency measures are recommended for consideration in OWMC's emergency response plan.

- notification to downstream users if accidental release is known or suspected
- spill clean-up program
- provision of alternative water supplies, if necessary.

° Monitoring program - continued study of water quality at the facility is required as a means of assessing impacts. Continuous real-time monitoring of storm water discharge from the site and of the receiving stream is recommended. Selection of parameters and instrumentation should be deferred until just prior to construction of the facility to ensure that the most recent advancements in instrumentation are incorporated into the design of the monitoring program. Regulatory requirements will mandate monitoring frequency and parameter coverage. Quality assurance of data will be vital.

As noted in Section 2.2.1, for this study it was assumed that no contamination of surface water would occur from contaminated ground water (leachate) from the landfill. This assumption was predicated on the adoption of the shallow entombed landfill concept and the downward flow of infiltrating ground water. The validity of this assumption should be confirmed as a result of ongoing work on:

° determination of ground water transport parameters (e.g. diffusion and adsorption coefficients);
° more complete characterization of leachate chemistry;
° better definition of soil attenuation processes

Further surface water impact analysis may be required as a result of these ongoing studies. Regardless, monitoring of surface waters will be essential to confirmation of water quality and water quality impacts.

PART 1
BASELINE CONDITIONS

PART 1 - BASELINE CONDITIONS

CHAPTER 1
INTRODUCTION

1.1 PURPOSE OF THIS REPORT

This report documents the surface water resources studies carried out as part of Phase 4B of the Ontario Waste Management Corporation's (OWMC) Facilities Development Process. Phase 4B involves detailed assessments of the Preferred Site and surrounding area based on the existing (baseline) conditions and the potential effects of the central operating area and landfill operations.

The specific objectives of Phase 4B are to:

1. Define the existing environmental conditions (baseline) of the preferred siting option.

2. Predict and assess potential risks and impacts that may be associated with the proposed facility design and operations.

3. Identify and develop appropriate mitigative measures to minimize the potential risks and impacts associated with the proposed facility design and operations.

4. Predict residual risks and impacts after implementation of proposed mitigative measures.

5. Identify and develop monitoring programs that will be implemented to assess the effectiveness of the design and operations in minimizing risks and impacts.

6. Prepare documentation to meet the requirements of Ontario's Environmental Assessment Act.

For surface water, the Phase 4B studies have focused on flooding and drainage issues, local uses of the surface water resource and on quality and quantity of surface waters both now and in the future. Accordingly, this report:

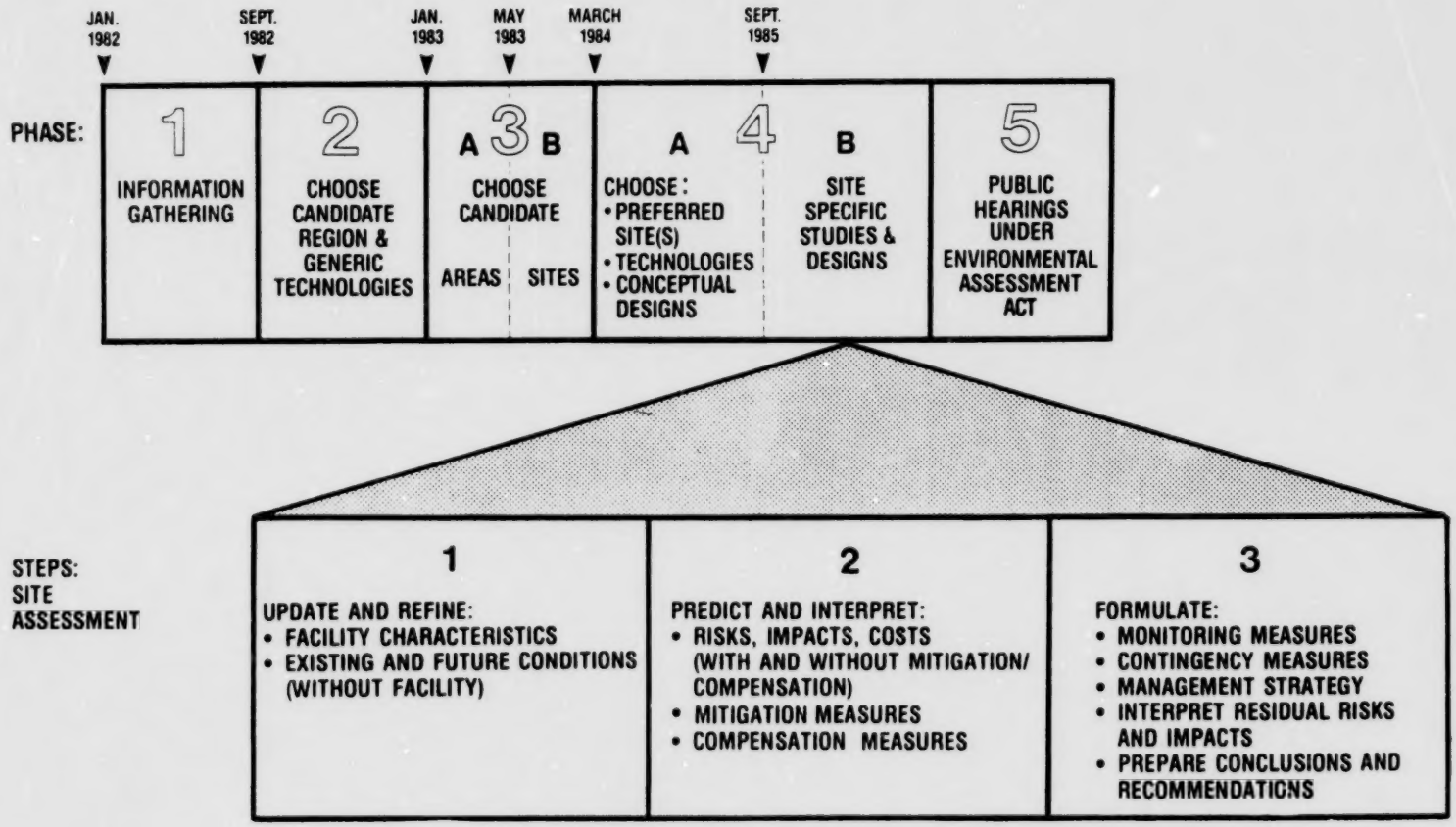
- Documents the existing state of surface water resources on-site and in adjacent watercourses, from both the quantity and quality perspectives.

- Considers the surface water component of the Phase 4A site selection process in relation to the enhanced level of data available for the Preferred Site and design refinements made during Phase 4B.

- Documents the impacts on surface water resources of the area associated with development and operation of the proposed facilities, together with recommended mitigative measures, a long-term monitoring program and contingency measures.

1.2 BACKGROUND INFORMATION

In 1982, OWMC embarked on a five-phase Facilities Development Process for the establishment and operation of a special waste treatment disposal system for Ontario (see Figure 1.1).



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FACILITIES DEVELOPMENT PROCESS

Figure 1.1

The first three phases involved information gathering, selection of appropriate waste treatment process technologies, and reduction of the siting options from a large geographic region and 20 candidate areas, down to 152 potential site areas, to 16 potential sites and further down to eight candidate sites.

Phase 4A involved selection of a preferred site (Figure 1.2) from the eight candidate sites. Following the detailed investigations of the Preferred Site (Phase 4B), OWMC will be submitting its siting and facility development proposal for review under the Environmental Assessment Act. Public hearings will follow the review period.

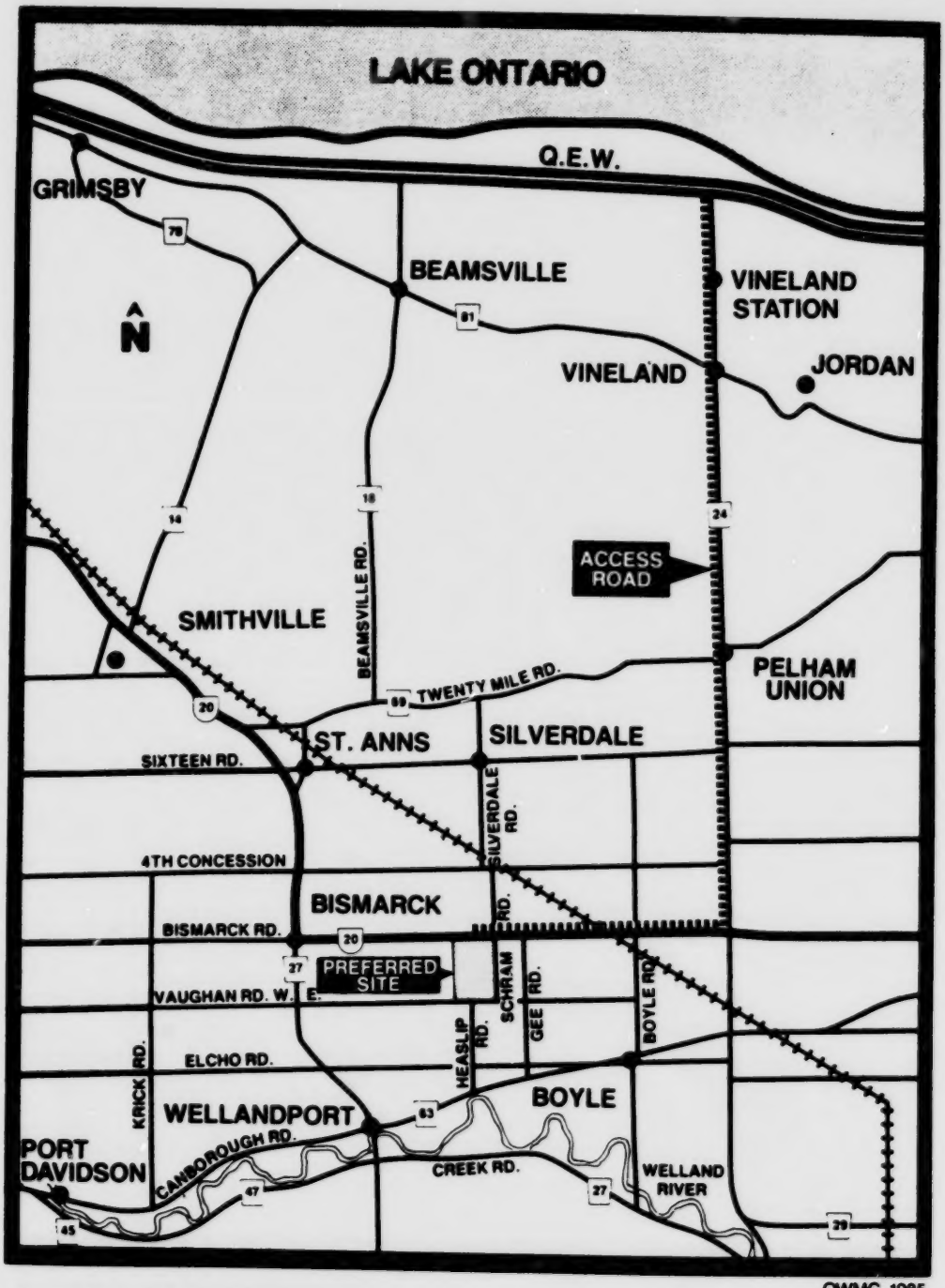
1.3 SCOPE OF WORK

While the level of investigative detail in Phase 4A was sufficient to meet site selection objectives, a much more rigorous study of the surface water resources of the Preferred Site has been undertaken in Phase 4B. This analysis was designed to provide a complete description of the existing (baseline) conditions, upon which impacts of the construction and operation of the facility could be predicted and against which any future changes in the surface water environment can be compared. While valuable data was obtained from existing secondary sources and used in the Phase 4B studies, additional detailed information on water quality, quantity and use was collected locally.

The scope of the Phase 4B surface water resources study included the following major elements:

- Collection and review of existing hydrometeorological data, streamflow records and water quality data.

Township of West Lincoln, Regional Municipality of Niagara. Local Detail.



OWMC, 1985.

0 1 2 3 4 Miles

0 1 2 3 4 Kilometres

OWMC Ontario Waste Management Corporation

DILLON

OWMC PREFERRED SITE

Figure 1.2

- Development of a detailed protocol manual for water quantity/quality data acquisition for both field and laboratory components.

- Planning and establishment of a water quality/streamflow monitoring network, including snow and sediment sampling.

- Preparation and implementation of a sampling schedule to adequately characterize water quality in local watercourses on a seasonal basis and for selected storm events (over a period of one year).

- Measurement of water levels and streamflows at key locations and times to characterize the hydrologic regime of local watercourses (over a period of one year).

- Interview landowners on-site and in the site vicinity to establish the use(s) of local surface water resources and the existing conditions for flooding and drainage.

- Conduct a hydrologic/hydraulic analysis of the existing on-site drainage for a range of design storms using hydrologic computer modelling and local culvert hydraulics.

- Determine the potential for on-site flooding from off-site watercourses.

- Predict impacts of the construction and operation of the proposed facilities on the quantity and quality of surface water in local watercourses.

- Propose appropriate mitigative measures and define residual impacts.

- Recommend a long-term monitoring program for the surface water features necessary to assess actual impacts.

- Provide input to the OWMC contingency plan.

- Provide surface water data/analysis for other Phase 4B studies including the assessment of risk from transportation spills into surface water and ecorisk studies (for Environ), the evaluation of site servicing options (for M.M. Dillon), preliminary landfill design (for M.M. Dillon), and engineering (for Monenco).

- Provide input on surface water considerations to the overall Environmental Assessment documentation (OWMC, 1987).

1.4 STUDY AREAS AND TIME HORIZONS

1.4.1 STUDY AREAS

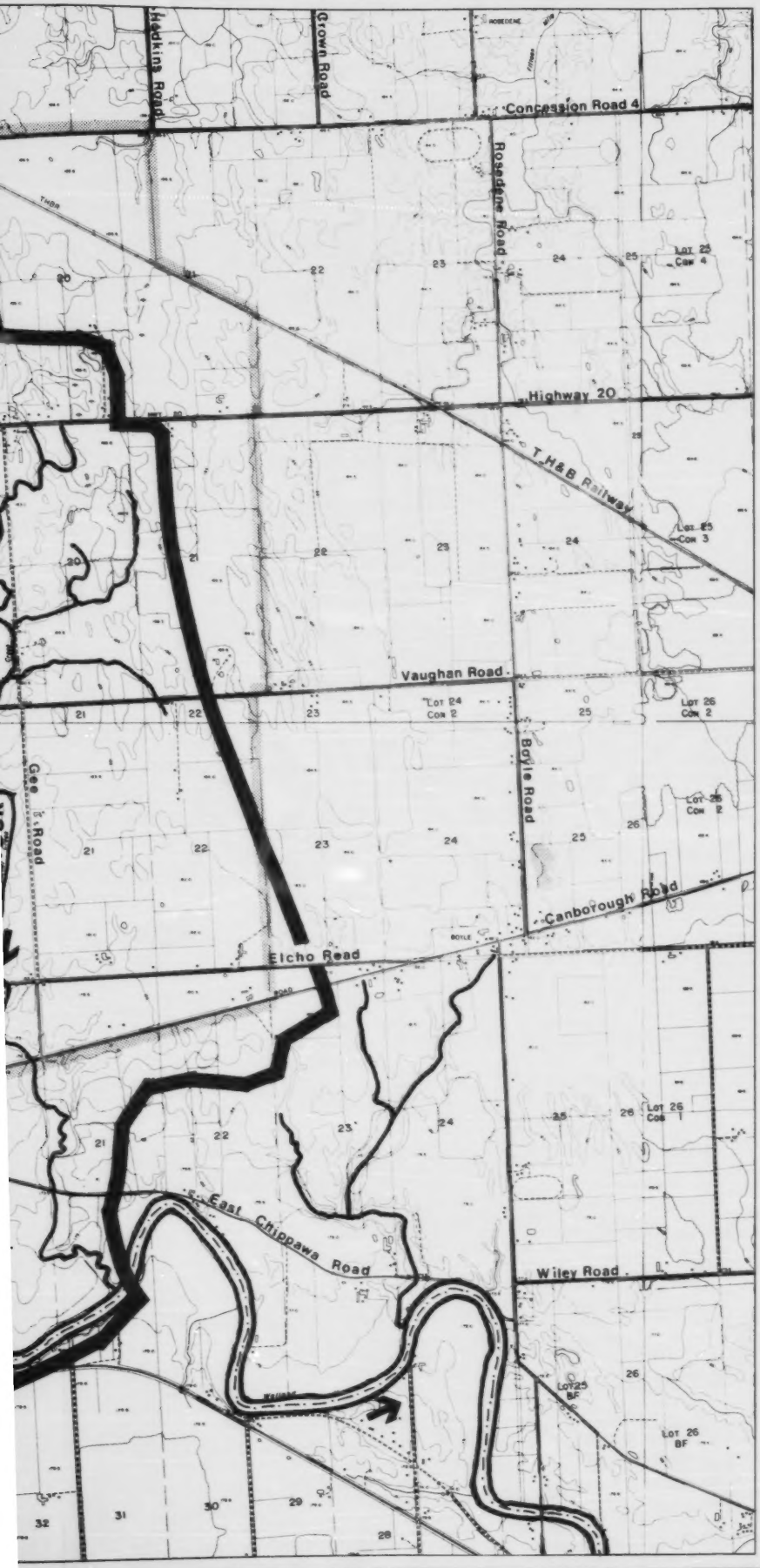
Study areas of significance for the surface water investigation were divided into three categories:

1. Site
2. Site Vicinity
3. Regional

The site and site vicinity boundaries for surface water are shown on Figure 1.3. The site vicinity boundary logically follows surface drainage boundaries of local watercourses in proximity to the site and, in particular, includes local watercourses downstream of the site which may be affected in some way by OWMC activities.

The regional area of significance for the surface water study covers the Welland River watershed (see Figure 1.4). The Welland River is the major receiving watercourse for all site surface drainage under existing conditions and will continue to receive uncontaminated runoff from much of the site in future. The flow regime of the Welland River and its existing water quality define the baseline against which OWMC operations were assessed.

Book Road
Silverdale Road
Hoskins Road
Schram Road
Heaslip Road
Geo. Road
Beaver Creek Tributary
9C Creek
Sucker Creek
Beaver Creek
Regional Road 63
Welland River
WELLANDPORT
LOT 17 CON 4
LOT 18 CON 2
LOT 17 CON 1



OWMC Ontario Waste Management Corporation

Consultant:

DILLON

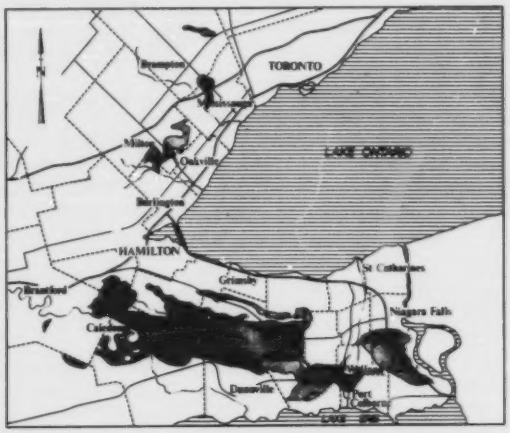
Legend:

- Site Boundary
- Site Vicinity Boundary for Surface Water Study
- Direction of Flow

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: OWMC PREFERRED SITE

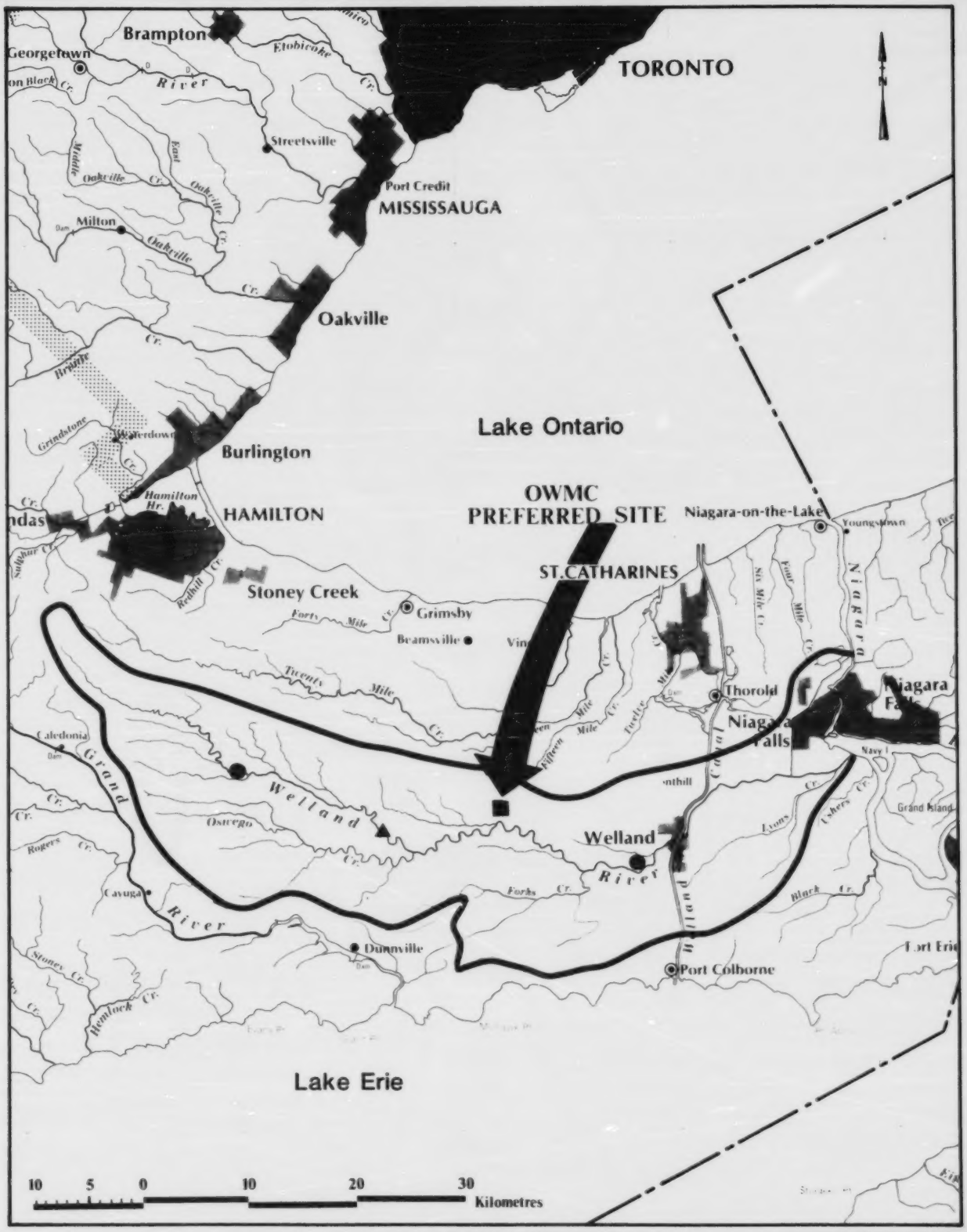
Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

STUDY AREA BOUNDARIES

Figure 1.3



OWMC Ontario Waste Management Corporation

▲ Water Survey of Canada Streamflow Station

● M.O.E. Water Quality Stations

DILLON — Watershed Boundary

WELLAND RIVER WATERSHED

Figure 1.4

1.4.2 TIME HORIZONS

For the surface water resources assessment several different time frames are relevant.

Firstly, the documentation of baseline conditions, throughout 1986, presents the conditions of the surface water resources prevailing prior to any construction by OWMC.

For the construction period, the impact assessment focused on the potential impacts of construction activity on off-site watercourses. In particular, nuisance impacts such as erosion and downstream sedimentation are dealt with here. However, on-site construction impacts are considered by the engineering consultant, Monenco Ltd. (Monenco, 1987b).

For the operational phase and post-operations period, off-site impacts for both streamflow and water quality are relevant. Streamflow conditions are examined for the ultimate development conditions (with full development of the landfill and at peak facility capacity) and after facility closure (post operational). In the absence of any treated effluents discharging to local watercourses, water quality impacts for the operational period relate primarily to nuisance impacts such as erosion and downstream sedimentation, to possible deterioration in Welland River water quality resulting from OWMC water takings and to the potential release of contaminated storm drainage to the Welland River.

1.5 REPORT FORMAT

The Site Assessment Report is divided into three volumes. Volume 1 (this volume) is further subdivided into two parts. Part 1 presents a detailed description of the existing baseline conditions and contains a summary of results of the streamflow and water quality monitoring carried out during 1986. Part 2 presents

the results of our study of predicted changes to the surface water environment as a result of OWMC activities, together with proposed mitigative measures, residual impacts and recommendations for monitoring.

Volume 2 of the Site Assessment Report contains several technical appendices in support of Volume 1.

A companion protocol document (Volume 3) has been prepared detailing procedures used for conducting water quality sampling and streamflow measurements, quality assurance requirements and detailed analytical and laboratory quality control procedures.

Part 1 (Baseline Conditions) of the Site Assessment Report is presented in three major chapters. Chapter 1 is an introductory chapter which outlines the purpose of the study, provides an overview of the work scope for Phase 4B and identifies the study areas and time horizons for investigation.

Chapter 2 summarizes the study approach and methods used for data collection, compilation and analysis. This chapter also identifies agency and public contacts made during the Phase 4B study and presents the environmental framework for the study in the form of a summary of water quality regulations and guidelines.

The third chapter presents a detailed description of the existing surface water resources by study area (site, site vicinity and Regional). Historical data is presented on streamflows, water levels and water quality. The influence of Ontario Hydro operations on water levels in the Welland River is documented. Chapter 3 also describes the runoff potential from the site under various rainfall conditions and assesses the existing drainage system. Existing uses of surface water on-site and in the site vicinity are summarized based on interviews conducted with local residents.

Part 2 (Impact Assessment) of the Site Assessment Report is presented in four chapters (4 through 7). The contents of Part 2 are summarized in Section 4.1.

A list of references is presented at the end of this volume.

1.6 STUDY TEAM

The Phase 4B surface water program was conducted by Dillon on behalf of OWMC. The study team included:

Project Manager	-	A.K. Mitchell, P.Eng.
Hydrology	-	W.A. Concessi, P.Eng.
Water Chemistry	-	L.E. Johnston, Ph.D.
Quality Assurance	-	C.M. Williams, B.Sc.
Field Coordinators	-	P.D. Duever, M.A.Sc.
	-	J.D.R. McEwen, P.Eng.

Gartner Lee Limited was a sub-consultant on the project responsible for the water use survey, the installation of staff gauges and the collection of streamflow data. The Gartner Lee study team included:

Project Coordinator	-	J.E. O'Neill, B.Sc.
Streamflow	-	J.J. McLean, M.Sc., P.Eng.
Water Use Survey	-	N.M. Woerns, M.Sc.

Analytical laboratories used for water quality analysis included:

- Barringer Magenta Limited;
- Standard Biological Limited;
- Ontario Research Foundation;
- Mann Testing Limited;
- Zenon Environmental Laboratories.

CHAPTER 2
STUDY APPROACHES AND METHODS

2.1 INTRODUCTION

This chapter summarizes the study approach and methods used for data collection, compilation and analysis. Assumptions adopted for this study, together with limitations of the data base and analyses, are described. The involvement of government agencies and the public, in the Phase 4B Surface Water Study is presented. This chapter also develops the environmental setting within which the study is set.

2.2 STUDY ASSUMPTIONS

2.2.1 SURFACE DRAINAGE MANAGEMENT FEATURES

The Phase 4B Surface Water Resources Study is based on a number of surface drainage management features as defined by Monenco (1987a) and summarized below. Many of these facility characteristics are

similar to those used for the Phase 4A analysis. However, a number of other key surface drainage management features have been added or modified as a result of the detailed site specific investigations for Phase 4B. These new or modified facility characteristics have been marked with an asterisk (*) for identification.

1. Within the central operating area, water from building and roof areas, grassed areas and other clean areas where no spillages are likely to occur will be collected in a storm water pond and will be discharged off-site to a suitable local watercourse, after testing. If testing indicates the runoff has been contaminated, it will be pumped to the physical/chemical treatment plant.

2. Potentially contaminated water from roads and other specified areas in the central operating area will be directed to a separate holding pond and also released to a local watercourse following verification of acceptable quality. If the water is found to be contaminated, it will be sent to the physical/chemical treatment plant.

3. Runoff and/or spillage from waste storage areas or other areas (classified as contaminated) within the central operating area will be contained and pumped to the physical/chemical treatment plant or incinerator.

4. Uncontaminated surface water from outside the central operating area will be controlled for peak flow reduction but not for retention and testing. The uncontaminated runoff will originate only from areas where the risk of contamination is very low (i.e. from undeveloped parts of the landfill and from completed landfill areas).

*5. Any surface water from the landfill operating area which may come in contact with solidified waste material will be isolated and directed to potentially contaminated water storage ponds. Water in the ponds will be tested, and if contaminated, will be discharged by the leachate transmission system to the physical/chemical plant for treatment. If uncontaminated, it will be released to the surface drainage system. Areas designated as potentially contaminated include:

- active excavation area
- access roads for solidified material transport
- truck load-out area for solidified material
- pipeline routes for leachate transmission

6. Treated waste water from the physical/chemical treatment plant will not be discharged to local watercourses. Treated effluents will either be solidified or evaporated.

*7. Uncontaminated storm water from the site will be discharged to the Welland River via a storm sewer along Heaslip Road.

*8. Sanitary sewage will be trucked off-site to suitable sewage treatment facilities. It will not be discharged to the Welland River.

*9. The shallow entombed concept is assumed for landfill development. This concept results in the final contours of the landfill approximating pre-development conditions. During the Phase 4A analysis, a higher, steeper landform was assumed consistent with the conventional landfill concept.

*10. The risk of contaminated runoff occurring from the completed landfill area is very low since no untreated waste will be allowed into the landfill area. With the shallow entombed landfill (preferred option), a 5 m thick compacted clay cover will overlie the solidified mass, further limiting the opportunity for contamination of surface runoff. For this report, no contamination of surface water in swales and ditches was assumed from subsurface sources in the landfill.

2.2.2 SCOPE OF MONITORING/MONITORING ASSUMPTIONS

2.2.2.1 Parameter Selection

The physical, chemical and bacteriological parameters were selected for the water quality study to address regulatory, operational and public concerns for surface water quality. The parameters must define the water character and be sufficiently comprehensive to address the assessment of potential impacts from the OWMC facility. The surface water in the study area receives inputs from a variety of human activities, primarily from the agricultural sector. Account was also taken of possible contributions to water quality from the natural environment (local geological features). Finally, the atmospheric transport of man-made contaminants was considered as a potential contributor to the existing background water quality at the site.

The list of parameters is divided into seven categories:

1. Field
2. General Chemistry
3. Nutrients
4. Bacteriological
5. Trace Metals and Miscellaneous
6. Trace Organics (primarily from the United States Environmental Protection Agency (USEPA) Listing)
7. Pesticides

The sampling program was organized around this breakdown. The detailed listing of the 180 parameters is given in Appendix A (Volume 2) and a discussion on the rationale for selection under each heading follows.

1. Field. These measurements are subject to rapid change once water is removed from the surface water environment. This is caused by ongoing biological activity involving oxygen and carbon dioxide dissolved in the water. Temperature is a factor that is characteristic only of the field situation. pH indicates the acidic or basic (alkaline) character of water. It is impacted by temperature changes therefore it is of value to determine the pH of water at the actual field water temperature. Dissolved oxygen levels in natural waters depend on the physical, chemical and biological activities in the water. It is, therefore, a good indicator of water pollution. The ability for oxygen to dissolve in water varies with temperature and atmospheric pressure. As such, the dissolved oxygen content in water changes between day and night and seasonally. These factors make it necessary to determine dissolved oxygen levels in the field at the actual field temperature and pressure.

Conductivity is a measure of the water's ability to carry an electric current. This ability is directly dependent on the amount of acids, caustics and salts present in the water. Conductivity in water increases over time, when the water is not flowing, because of carbon dioxide gas adsorption. Therefore, it must be measured in the field.

2. General Chemistry. The parameters listed under General Chemistry can be used to describe the principal chemical character of the water. The parameters can be used to account for the majority of the dissolved and suspended matter in the water.

Many of these chemical species are conservative, i.e. they do not participate significantly in physical, chemical or biological processes in the water. They can therefore be used to follow seasonal or event-related effects causing dilution of the receiving water. Ground water contributions can be followed as the ground water composition is unlikely to change significantly in time. Gross inputs from human activity will be first detected by monitoring these parameters; subtle effects will rely on the less concentrated (trace) component monitoring.

3. Nutrients. Concentrations of these substances can reflect agricultural activity, sewage treatment plant (STP) discharges and normal seasonal biological activity in the river and drainage areas. They affect biological activity in the water-courses, particularly the capacity for algal growth. Algal growth, in turn, affects properties such as pH, dissolved oxygen and alkalinity. Establishing nutrient patterns and responses by stream biosystems is necessary in developing baseline performance for these streams in order that site-related effects on them can be distinguished from normal seasonal or event related changes.

The Biochemical Oxygen Demand (BOD) characterizes the river's likelihood of depleting its dissolved oxygen content, which would not only kill life forms requiring air to live (aerobic), but cause the river to become oxygen depleted or anaerobic and generate a variety of noxious by-products.

4. Bacteriological. The bacteriological parameters provide another indication of surface water quality. Those measured for this study are a very few of a host of bacteriological species that may exist in surface water. They point to pollutant discharges from human or animal sources.

Natural cycles in these parameters are expected based on seasonal inputs or seasonal or event flushing of the systems. Unaccounted for changes may indicate inputs of pollutants from unusual or artificial sources.

5. Trace Constituents. The trace constituents listed are either toxic to a variety of lifeforms or create an unaesthetic appearance or taste to the water. Phenol, cyanide and sulfide are included in this group because they exhibit similar characteristics. The presence of many of these chemicals in surface water is related to human activity. Some natural sources of these materials are possible. Modern analytical methods can detect small changes in these constituents from background levels and along with some trace organics provide a good first indication of problematic discharges.

6. Trace Organics (Primarily Priority Pollutants). The list of trace organics is derived from the priority pollutant listing produced by the USEPA (USEPA, 1980; USEPA, 1986) and was supplemented with trace organics identified by the MOE in their studies of the St. Clair (MOE, 1986a) and Niagara Rivers (MOE 1984d). As such they represent a comprehensive list of known toxic organic chemicals as well as those identified in the Ontario rivers. The EPA list was developed from American experience; inclusion in the list implies either a highly toxic material generally associated with industrial uses or a less toxic material found in industrial waste on a frequent basis. The list includes metals, all of which are listed in the trace metal grouping. The St. Clair River Studies (MOE, 1986a) sought a broad range of chlorinated species typical of the industrial contamination originating in the Sarnia area. By comparing these lists it was hoped that the vast majority of industrial contaminants arriving at the site by whatever route (airborne, waste related, etc.) would be monitored.

The Ministry of the Environment (MOE, 1987a) has developed a draft list of chemicals (for review) for which monitoring data may be required under MISA (Municipal-Industrial Strategy for Abatement) regulations. While not available for the 1986 surface water monitoring program, this new priority pollutant listing will be consulted with respect to future water quality monitoring for OWMC.

7. Pesticides. Many pesticides are included in EPA's priority pollutants list (USEPA, 1986). In addition to those, pesticides in common use in Ontario and particularly in the site vicinity, are analyzed. A seasonal fluctuation is expected for pesticides, as they are generally applied at specific times of the year and degrade at a significant rate after that.

2.2.2.2 Detection Limits

Analytical methods were selected in part on the basis of their limits of detection. It is well recognized from many assessments of Ontario surface water quality that contaminant levels are low (MOE, 1986). For low-level contaminants, it is necessary that the limits of detection be significantly lower than the water quality criteria or objectives for the contaminant. Otherwise the analysis would not permit an assessment relative to the objectives. Where very low concentrations are anticipated, as in the determination of surface water quality, detection must be capable with some certainty of indicating whether the contaminant is present. In principle, selection should be based on the ability to discriminate or detect at the levels of interest. Too little sensitivity would not provide the information; more sensitivity than required would in many cases pose an unnecessary analytical or preparative cost.

Where possible, this has been done. In some cases, measurement sensitivity requirements are too demanding. A method detection limit was adopted that would permit an assessment for most of the parameters in a specific chemical grouping.

The detection limit required can also be a function of the expected concentrations. In many cases the available detection limit is orders of magnitude below the expected level. In these cases the method is chosen for other reasons such as ease of processing, speed, etc.

The detection limits used in this study are discussed below and are presented in Appendix A.

1. Field Measurements. For pH, conductivity and temperature, detection limit is not a problem as mid-range values are anticipated. It is well recognized that surface water pH is in the range of 6.5 - 8.0 and temperature between 0°C and 30°C (MOE, 1986). For dissolved oxygen, levels in the mid-saturation range 3-8 mg/L) are expected, based on previous experience. Therefore, detection is generally expected well above the detection limits quoted and attainable for the field equipment used in this study.

2. General Chemistry. Detection limit is from 0.01 to 0.10 mg/L or better, depending on method. This is generally a small percentage of the level expected for the species. For chloride, sulphate, magnesium, calcium and sodium values from 5 to 50 mg/L are expected (MOE, 1986).

3. Nutrient Species. Detection limits are similar to the General Chemistry since the same type of methods are used. However, levels found are often below the detection limits. This is tolerable, since only relatively high nutrient concentrations will encourage algal growth. Trace amounts are of less interest, as their impacts on surface water impairment are negligible at trace levels.

For BOD, the detection limit is 1 mg/L. Values expected range from 5 to over 200 mg/L (MOE, 1986), indicating that this limit is adequate.

4. Biological Species. Bacterial analyses are done by colony-counting techniques. Values are reported from zero per 100 mL to populations exceeding millions per 100 mL. The objective for drinking water is zero and the method routinely permits the detection of zero colonies so that the detection limit is adequate.

5. Trace Metals and Miscellaneous. In this group drinking water objectives range down to 0.0002 mg/L (MOE, 1983) while levels of 0.00005 - 0.004 mg/L can be detected, using conventional techniques. Detection limits range from the objective levels to a few percent of the objective levels or less. Where the drinking water objectives are very low, as for lead, cadmium, chromium, arsenic or mercury, limits of detection are just adequate to ensure measurement at the objective level.

6. Trace Organics and Pesticides: These materials are present at very low concentrations in environmental samples. The objective concentrations vary over many orders-of-magnitude, but tend to be quite low in comparison to those for most of the previous parameters.

Detection limits available at the laboratories used in this study range from 0.2 to 5.0 ug/L for nitrogen/phosphorus pesticides, 10 to 200 ng/L for chlorinated pesticides, and 0.3 to 10 ug/L for other priority pollutants. With these detection levels an assessment of the impacts of these chemicals can be made, although the impacts on the most sensitive receptors, such as fish, may not always be addressed. The detection limits provide a comprehensive basis for the assessment of trace organic levels.

2.3 DATA COLLECTION PROCEDURES

2.3.1 DATA SOURCES

2.3.1.1 General

Numerous sources were consulted in the Phase 4B assessment of the surface water baseline conditions. These include:

- materials already in hand from earlier study phases and other hydrologic work previously conducted by Dillon.

- Contacts/meetings with relevant government agencies (local, provincial and federal).

- Direct contact with local residents to complete a surface water questionnaire (as part of a larger hydrogeological/ water use survey conducted by Gartner Lee Limited).

- Field observations and direct collection/measurement of water levels, streamflow and water quality sampling in local water-courses.

- New 1:2000 scale topographic mapping with 0.5 m contours of the site and part of the site vicinity.

A list of agency contacts and the type of information provided is contained in Section 2.7 and Appendix C.

A complete set of the field data collected is provided in Chapter 3 and Appendix K.

2.3.1.2 Water Use Survey

The use of surface water is characterized from the results of a survey of landowners and tenants. The survey was conducted by Gartner Lee Limited (1987) as part of a larger survey of both surface and ground water use in the vicinity of the proposed site. The survey addressed such items as the source of the residents' potable and non-potable water, reliance on cisterns or ponds and the use of surface water for livestock watering. The presence of tile drainage was recorded where the information was provided. The respondents were asked about flooding on their properties and soil erosion problems. The parts of the survey that pertain directly to the use of surface water were extracted from the interview forms for use in this report evaluation. A sample interview form is contained in Appendix B.

Attempts were made to conduct the interviews with the tenants and/or landowners for each property within the study area. Interviews with long time residents provided historical insight into water use and drainage features on several properties in the study area.

The study area includes the properties on site and adjacent to the site. The properties surrounding Sucker Creek are included together with the properties that lie downstream from the site, i.e. between the site and the Welland River.

2.3.2 WATER QUALITY AND QUANTITY MONITORING

2.3.2.1 Monitoring Schedule

The goal of a monitoring program is to obtain data which can be used to describe the water quantity and quality of the surface water. Conceptually it is possible to consider continuously monitoring the quantity and quality. In fact streamflow can be

obtained from level recording devices in a fairly straightforward manner. Continuous streamflow records are collected by the Water Survey of Canada for many rivers in Ontario (including the Welland River) and in other provinces. Water quality monitoring is more difficult given the complexity of the measurement and the multiplicity of parameters. In concept, it is still possible to consider a continuous record. In practical terms, however, it is only possible to take single point observations through the year in a manner that characterizes the major events on the surface streams during the year.

A series of sampling episodes was planned to characterize the water quantity and quality. The characteristic events and periods were chosen to cover all of the characteristic periods during the year.

The events and periods are listed in Table 2.1 which describes the overall sampling program for both quantity and quality. Continuous streamflow records from Water Survey of Canada (Environment Canada, 1987) were used to estimate river flows at monitoring sites on the Welland River. The choice of sampling locations is discussed below in Section 2.3.2.2; what follows immediately below is a discussion on the selection of the characteristic events or periods through the year. The discussion includes a rationale on the number of samples for each class of chemical. These are the same chemical classifications described under Parameter Selection, Section 2.2.2.1. The number of priority organics and pesticides were limited by the high cost of these analyses.

Winter Low. In mid-winter the flow in watercourses reduces to a seasonal minimum. Water flow in most watersheds is derived primarily from ground water discharge to surface water systems. The sampling episode should be after a significant period of

TABLE 2.1
SAMPLING SCHEDULE

Code: G = General Chemistry; N = Nutrients; B = Bacteriological; T = Trace Elements; Pr = Priority Organics; Ps = Pesticides

Site Station #3A*	**G**	**N**	**B**	**T**	**Pr**	**Ps**
Winter low	1	1	1	1	1	0
Freshet	3	3	3	3	0	0
Spring	1	1	1	1	1	1
Spring B	1	1	1	1	0	0
Summer Storm	3	3	3	3	0	3
Summer low	1	1	1	1	1	1
Fall A	1	1	1	1	1	1
Fall	1	1	1	1	0	0
Fall storm	3	3	3	3	0	0
Site Station #2A						
Spring B	1	1	1	1	1	1
Summer Storm	1	1	1	1	0	1
TOTAL	**17**	**17**	**17**	**17**	**5**	**8**
River Stations #4A and 4B						
Winter low	1	1	1	1	1	1
Spring	1	1	1	1	1	1
Summer low	1	1	1	1	1	1
Fall	1	1	1	1	1	1
TOTAL (sum X 2 for two stations)	**8**	**8**	**8**	**8**	**8**	**8**
Snow						
Comprehensive	1	1	0	1	1	0
Sediment						
Two river stations	2	2	0	2	2	2
GRAND TOTAL	**28**	**28**	**25**	**28**	**16**	**18**

* See Section 2.3.2.2 for sampling locations.

freezing weather. Priority organics found at this time would suggest a local anthroprogenic discharge from ground water. Pesticides would not be expected in the surface runoff.

Freshet. The first rush of spring snowmelt usually occurs as a short-term event often accompanied by rain. As such several samples should be taken over a short period of time to characterize the event. For this and other event samplings described below, it is preferable to take samples on the rising limb of the hydrograph, near the peak flow period and on the receding limb of the hydrograph. Contaminant concentrations are not synchronized with water flow; however they will likely peak early in the flow.

Atmospheric transport of some contaminants, which have accumulated in the snowpack, may be evidenced in this sample. However, trace organics and pesticides are unlikely to be found because of the high dilution of the streamflow.

Spring A and B. High flows occur as the snow pack melts and water drains systematically from the watersheds. There are two characteristic flow regimes, the first a highly turbid flow similar to the freshet but lasting for several weeks. Later in the spring flow remains high but the water tends to clear and the volume starts to decrease towards a seasonal minimum in late spring. The first spring event was selected for the first comprehensive definition of the water quality covering all parameters. The second spring sampling was aimed at providing additional information limited to the general chemistry, nutrient, bacteriological and trace metal parameters.

Summer Storm. From mid-June through early September, localized intense thunderstorm events are expected to cause significant flow in the watercourses. The event type sampling

with multiple samples as described above is warranted. In this case interest is focussed on any pesticides which may wash off the local agricultural areas. Priority organics, if present, are likely diluted to barely detectable levels so they have been excluded from the analyses. This event, as with others, is important in that it may contribute significantly to the year-long load of contaminants in the river streams.

Summer Low. In mid-summer the lowest flows during the year are encountered. Biological activity is likely at a maximum and pesticides and priority organics may be found due to availability and lack of diluting rainfall. Some local watercourses may be dry and/or stagnant in the study area.

Fall A and B. In the fall precipitation normally increases and evapotranspiration falls off markedly so that ground water systems fill up and a non-event base flow develops in the watercourses. As indicated for the spring sampling, two periods are characteristic, the first perhaps a more turbid period with the accumulation of summer's contamination washing off into the watercourses. Pesticides and priority organics may increase to significant levels in the first period. The second period is valuable because it reflects the longer term flow that exists through the last two months of the year. The flow tends to be less turbid but at higher sustained levels as more frequent rains occur. A second sampling on a less comprehensive base is useful to complete the information base on loadings, etc.

Fall Storm. The fall season typically is characterized by significant short-term precipitation events. These events are longer lasting and more predictable than the spring and summer events. They also warrant monitoring on the rising and receding limbs and at the peak flow. Again, data obtained here will

significantly contribute to the overall loading picture for the watersheds. Pesticides and priority organics are not likely to be found at these times.

Snow. During the winter a snow sample was also collected. This sample includes priority organics but not pesticides; atmospheric transport of these contaminants plus trace metals may show up in this sample. Preferably, the sample is a depth integrated sample collected after several snow accumulations have occurred.

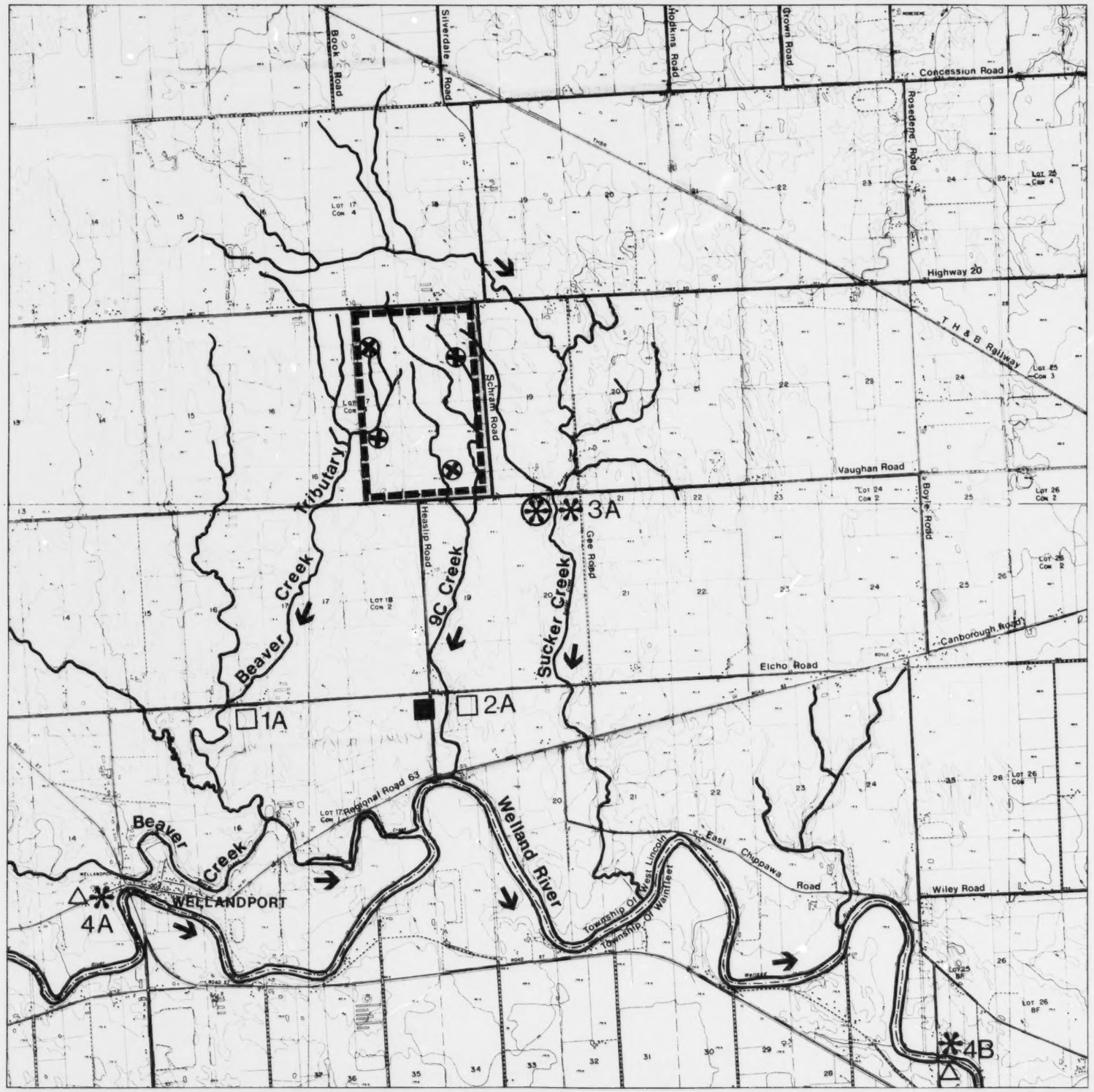
Sediments. One sampling at two locations was planned from the Welland River and scheduled for the summer low flow period. This increases chances of detecting contaminants because time has been allowed for sediments to settle and the scouring of the bottom of the streambed is at a minimum.

2.3.2.2 Monitoring Locations

The monitoring locations for streamflow and water quality are given on Figure 2.1. The sample station numbers in Table 2.1 above and in the following discussion refer to this figure.

Streamflow estimates for the Welland River sites (4A and 4B) were derived by transposing flows from the Water Survey of Canada gauging station below Caistor Corners (Station No. 02HA007) (Environment Canada, 1987).

The streamflow monitoring station on Sucker Creek at Vaughan Road (3A) was selected to typify the local surface drainage regime and hence was designated as a primary streamflow station with more frequent monitoring. This location on Sucker Creek was preferred over the crossing at Elcho Road which tends to be overtopped under moderate to high flows. The Elcho Road crossing is also complicated by twin corrugated steel pipe (CSP) culverts rather than a single conduit.



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Consultant:

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Legend:

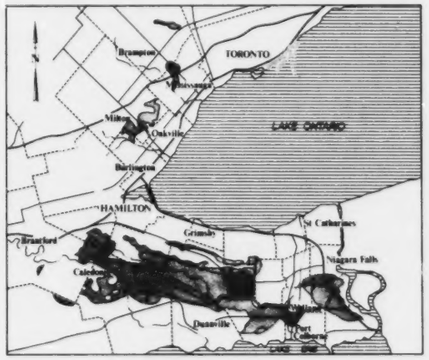
MONITORING STATIONS

- Stream Flow (primary)
- Water Quality (primary)
- Stream Flow (secondary)
- Water Quality (secondary)
- Snow Sampling Station
- Sediment Sampling Station
- Direction of Flow
- Site Boundary

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: OWMC PREFERRED SITE

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

WATER QUANTITY/QUALITY MONITORING STATIONS

Figure 2.1

Streamflow monitoring stations on the tributary of Beaver Creek (1A) and on 9C Creek (2A) at Elcho Road were preferred over the crossings at Vaughan Road. The Elcho Road sites have larger drainage areas than at Vaughan Road and these sites were better suited to field measurement of the velocity distribution in the channel. These two stations were treated as secondary stations and only occasional streamflow/water level monitoring was conducted.

Water quality samples were taken at four sites: the bridge at Wellandport (Station 4A), Pearson Bridge at Boyle Road (Station 4B), Sucker Creek at Vaughan Road (Station 3A) and 9C Creek at Elcho Road (Station 2A). The sites were selected to characterize the water bodies downstream of the Preferred Site.

The Sucker Creek (Station 3A) was chosen as representative of water quality in the intermittent watercourses in the site vicinity. Sucker Creek represents the largest drainage basin in the immediate vicinity of the site. Sampling of 9C Creek (Station 2A) for two storm events was undertaken to characterize runoff from the Preferred Site and from lands immediately downstream of the site.

The bridge on the Welland River at Wellandport is normally upstream of runoff from the site. However, fluctuating water levels, resulting from Ontario Hydro operations downstream, can stall or reverse flow in this section of the river. At Pearson Bridge, any impact of flow from 9C Creek or Sucker Creek would be felt; sampling there established the difference attributable to the community of Wellandport, the local creeks including Beaver Creek, 9C Creek and Sucker Creek and agricultural activity.

Sampling in the river nearer the creek outfalls would have more precisely identified the effects of the creeks; however, the advantage of sampling upstream, out of the site's normal zone of

influence, would have been lost. In addition, sampling sites at bridges are much safer and more convenient and are also more accessible in times of heavy flow. This facilitates sampling at the same location in the river for all sampling episodes.

Sediment properties are significant indicators of materials deposited from stream water. However, sediment may have been present for many years or it may be recently deposited. A high volume event may deposit more sediment on top of old, or it may flush out the old and replace it as velocity falls; or it may behave differently according to flow volume and river bed geometry. For the Phase 4B studies, a sediment sample was taken on one occasion at both the Wellandport and Pearson bridges, during the "Summer Low" period, following an extremely rainy month. Sediment collected should contain elements from recent runoff and deposition from slow moving water, as well as long-term deposits. Interpretation of future results will have to account for variation due to flow conditions.

2.3.2.3 Streamflow Water Level Measurements

Similar to the water quality sampling program, streamflow measurements in the local watercourses were non-continuous and were taken only to characterize the general hydrologic regime and to define streamflow during water quality sampling events.

Standard metric staff gauges were installed at selected locations as part of the program to characterize the streamflow/water levels in the vicinity if the site. These locations were:

Station 1A - Un-named tributary of Beaver Creek on Elcho Road

Station 2A - 9C Creek at Elcho Road

Station 3A - Sucker Creek at Vaughan Road

Station 4A - Welland River at Wellandport

Station 4B - Welland River at the Pearson Bridge.

The streamflow at Stations 1A, 2A and 3A was gauged on several occasions during the year. The gauging times were chosen to be representative of a range of flow conditions, i.e. high, moderate and low flow conditions.

Water levels at Station 3A were measured on a frequent, but irregular, basis during 1986. Levels at all other stations were measured less frequently and generally only during sampling episodes and on occasions for flow measurement.

Continuous streamflow data is available for the Welland River from an existing Water Survey of Canada gauging station (Environment Canada, 1987) upstream from the site (refer to Figure 1.4).

2.3.2.4 Laboratory Selection

Five laboratories were selected to complete the full analytical requirements and provide the inter-lab quality assurance. The laboratories and their responsibilities are as follows:

- Barringer Magenta Limited: General chemistry, nutrient, trace metal and miscellaneous analysis on all samples collected. Priority organic and pesticide analysis on quality assurance samples until November 1986.

- Standard Biological Limited: Bacteriological parameters and biochemical oxygen demand on all samples collected.

- Ontario Research Foundation: All parameters (except priority organics and pesticides) for the quality assurance samples.

- Mann Testing Limited: Priority organics and pesticides analysis on all samples collected.

- Zenon Environmental Laboratories: Priority organic and pesticide analysis on quality assurance samples from November 1986 to present.

2.3.2.5 Quality Assurance/Quality Control Data

In this baseline water quality assessment, it is of primary importance to know that the study data obtained is as representative as possible of the actual water quality in Sucker Creek, 9C Creek and the Welland River. Therefore, it is necessary to ensure the analytical water quality data obtained are accurate, precise, consistent and well documented. A rigorous quality assurance/quality control (QA/QC) system has been implemented to meet these requirements.

Quality assurance can be defined as: "those operations and procedures which are undertaken to provide measurement data of stated quality with a stated probability of being right" (Taylor, J.K., 1985). More specifically, quality assurance can be divided into two separate components. Quality assurance itself is a management function in which quality control procedures are developed, operational procedures are described in detail in a formal protocol, employees are trained in both quality control and operations, and quality control data are checked. The Protocol Document (Volume 3 of this Report) is a very important part of the quality assurance implemented in this assessment. Quality control procedures are procedures implemented by the field or laboratory technician which help ensure that the methods being used for field sampling and analysis are operating according to specification. For water quality assessment these quality control procedures include:

- collection of field blank samples for analysis:

- labelling and documenting of field samples;

- regular analysis of duplicate samples, samples of known concentration and distilled water blank samples, to ensure that the analytical systems are operating correctly;

- analysis of duplicate samples by different laboratories to ensure that comparable results are obtained.

These specific quality control procedures are detailed in Volume 3, the Protocol Document, developed for this study. In general, these protocols ensure that a sample is taken, submitted to the laboratories and analyzed in a prescribed manner. To ensure that data produced was indeed of high quality, the laboratories were requested to generate QA/QC data on the water quality samples analyzed. This QA/OC data was generated in two ways:

- intra-laboratory QA/QC data
- inter-laboratory QA/QC data

Intra-laboratory QA/QC procedures are procedures undertaken within each of the laboratories. They are conducted to ensure the day-to-day quality of the analyses being done. Intra-laboratory QA/QC includes such activities as:

- using only well trained personnel for analysis;

- documenting analytical procedures;

- purchasing analytical standards and chemicals from reputable suppliers;

- maintaining a rigorous laboratory and glassware cleanliness program;

- conducting a high level management review of all analytical data prior to release to the client to ensure data quality.

All of the above are quality assurance activities.

Intra-laboratory quality control procedures also involve the analysis of:

- known standard samples
- duplicate samples, and
- laboratory reagent blanks

These 'quality control samples' are analyzed in the same manner as unknown samples. The laboratories plot the results of the 'quality control sample' analyses onto daily Control Charts. These Control Charts are then used to check the accuracy and precision of the analytical instrument or method being used. If questionable 'quality control sample' results are obtained in an analytical run then all analytical results obtained for unknown samples during that run are also questioned and repeated if necessary. No analytical results are released from the laboratories unless QA/QC sample results show that the analytical systems are operating correctly and as such that the unknown sample analyses have a high probability of being correct.

Inter-laboratory quality assurance/quality control is undertaken by having two or more laboratories analyze replicate unknown samples using their own and possibly different analytical techniques. The analytical results generated by the different laboratories should be comparable to within an allowable error which is assessed individually for specific chemical or

bacteriological parameters. In this OWMC surface water quality assessment, approximately 10% of the water samples collected were analyzed in duplicate for all parameters, by two different laboratories. Inter-laboratory QA/QC results are reviewed in Section 3 of this report.

The QA/QC procedures and the QA/QC data generated ensure the quality and validity of the water quality analyses obtained in this assessment. The procedures used are state-of-the-art and should ensure that the water quality data obtained in this study is accurate, precise and representative of actual river/creek water quality.

2.3.2.6 QA/QC in Bacteriological Analysis

Bacteriological analysis is conducted by allowing bacteriological growth, under controlled conditions, onto a culture medium which is specific to an individual bacteria. The cultured bacteria are then counted using a microscope. Because these procedures involve the culturing or growth of a bacteria, it is impossible to develop and analyze standard samples of a bacterial colony. As a result, QA/QC methods in bacteriological laboratories differ from those in chemical laboratories. Bacteriological laboratories do analyze quality control duplicate and blank samples.

2.4 STUDY LIMITATIONS

The surface water resouces study objectives were detailed in Section 1.1. The principal objective of the baseline assessment is to characterize the water quality and quantity that presently exists at the OWMC facilities site. Based on that characterization, the OWMC facility operation is to be superimposed and the

impacts of the operation assessed. Mitigation of unacceptable impacts are to be suggested. Part 1 of this report provides a summary of the existing baseline conditions data. Limitations of obtaining this data in the context of the objectives of the overall study are discussed below.

Sampling Frequency

This study may be limited by the frequency of sampling but it must be remembered that it is only the first year of an ongoing baseline monitoring program. It is practical to undertake a limited program in the first year to identify problem areas that may warrant more intensive study in subsequent years. For example, analysis in the first year of the program for pesticides may reveal specific use and fate patterns unique to the West Lincoln environment.

Sample Location

The sample locations on the Welland River were selected to provide data upstream and downstream of the potential OWMC outfall and on streams potentially accepting OWMC discharge or at least streams that are draining the site. These locations were selected on the basis of potential impacts from direct discharges to surface water either through treated sewage discharge (not proposed) or surface drainage (storm water). Other aspects of potential surface water contamination (e.g. transportation spills into surface water and air emissions) are covered by other studies (Environ, 1987).

Sampling upstream and downstream of the proposed storm water outfall will establish a database on water quality for a potentially impacted reach of the river (downstream) and a control point (upstream). The upstream control point will, in the future,

provide data on the regional impacts on Welland River water quality not attributable to OWMC operations.

Site drainage presently takes place through a number of small watersheds. The streams receiving water from the site vary in size and therefore are all intermittent streams to a greater or lesser degree. The largest stream was selected to ensure an available flow during sampling periods of seasonal high flow and during storm events.

Water Quality Parameters Selected

Inorganic and trace constituent parameters are drawn largely from drinking water objectives for Ontario. The list corresponds closely with lists of chemicals of concern expressed by environmental regulators in Ontario. The inorganic group could have been more comprehensive but as a first year list it would indicate problematic areas by grouping. For example, a wider range of trace metal analyses are available if the selected parameters indicate a problem.

Hydrologic Regime

Normally, in characterizing a river system, there is an assumption that the river flows and has water quality characteristics that change continuously through the seasons.

The Welland River and the relatively small creeks draining the site are atypical in the context of developing 'normal' backgrounds for river systems. The creeks are dry in periods of low rainfall and the Welland River can be stagnant. In addition, the Welland River can experience flow reversal under the control of Ontario Hydro. These factors made the selection of upstream/downstream stations difficult.

Meteorological Year 1986

It is a maxim that a 'normal' year does not exist. However, it appears that 1986 has been atypical of any concept of normal. The 1986 flow regime for the Welland River is described in Section 3.2.3. Given the wet summer, the low flow may prove to be anomalous and the sampling of a summer storm event was compromised by too many storms, preventing a significant dry spell from occurring before the event was sampled.

The current monitoring program will continue and a wide range of weather conditions is expected in future years.

Hydrologic Modelling

A mathematical hydrologic model has been used in this study to characterize the existing hydrologic response of the site to defined rainfall events and to predict the impact of site development on runoff peaks and volumes, for similar events. The model used for this analysis is widely accepted in Ontario for similar applications. However, a mathematical model can only approximate the actual rainfall/runoff processes. A number of simplifying assumptions are built into the model. Furthermore the results are limited by the representativeness of the assumed rainfall distribution and other input parameters.

The modelling assumptions are discussed in Sections 2.5.2 and 5.2 and in Appendix 'D'.

2.5 DATA COMPILATION AND ANALYSIS PROCEDURES

Compilation and analysis of data varied according to the study area (i.e. site and site vicinity, Regional-Welland River). Accordingly, the description of procedures for data handling and analysis has been sub-divided in a similar fashion.

2.5.1 REGIONAL - WELLAND RIVER

2.5.1.1 Streamflow and Water levels

Water levels in the lower Welland River are controlled by Ontario Hydro operations downstream. This influence extends upstream beyond Wellandport for a distance exceeding 20 km. Consequently, water levels in the Welland River near the Preferred Site are not always indicative of flow in the River. This is particularly true for low to moderate flow periods when the hydraulic gradient is small.

The Water Survey of Canada (WSC) gauging station below Caister Corners (Station No. 02HA007) is beyond the influence of Ontario Hydro operations and hence has a unique relationship between river stage and flow.

To estimate streamflow in the Welland River near the Preferred Site, the WSC flow records have been transposed downstream using a standard relationship between peak flow and drainage area. The relationship has been generally verified based on hydrologic modelling carried out for the Niagara Peninsula Conservation Authority (Dillon, 1985).

The relationship is given as:

$$Q_2 = Q_1 \left(\frac{A_2}{A_1}\right)^{0.75}$$

For this application:

A_1 = drainage area above the WSC Station (below Caistor Corners) = 222 km^2

A_2 = drainage area above the Welland River/Beaver Creek confluence = 548 km^2

For the Welland River, the expected streamflows near the Preferred Site will be approximately double the flows at the WSC gauging station. This approximation is considered reasonable for use in this study.

The Welland River Study (Dillon 1985) also defined flood levels for a range of return periods, along the Welland River. This existing data was used to plot the regulatory flood levels for the Welland River in the vicinity of the Preferred Site.

During the period for baseline data collections, water levels were monitored at two locations on the Welland River; one at Wellandport upstream of the proposed outfall and one downstream at the Pearson Bridge. Water levels were recorded using a standard metric staff gauge mounted on a steel post which had been driven into the river bed. Fly leveling was carried out to determine the geodetic elevation of the staff gauge '0' and hence the geodetic elevation of water levels at the time of reading.

2.5.1.2 Water Balance

Water balance techniques are a means of accounting for the fate of precipitation once it reaches the ground surface. Precipitation is normally lost through the processes of runoff, evapotranspiration, surface storage and sub-surface storage. Over a long period of record, the effect of changes in storage on the water balance are usually small, and can be neglected. This results in the simplified water balance equation given by:

$$P = E + R$$

where P = precipitation
E = evapotranspiration
R = runoff

Estimates of P and R were obtained from recorded data, the residual being considered evapotranspiration. Long-term average values of precipitation were obtained from the Atmospheric Environment Service (Environment Canada, 1982) for several gauges in the area. Long-term average values of runoff were obtained from Water Survey of Canada (Environment Canada, 1986 and Moin and Shaw, 1985).

For this study, a regional water balance was prepared using available streamflow data for the Welland River, together with regional precipitation data. Strictly speaking, the water balance calculations are applicable to the upper 25% of the Welland River watershed (i.e. upstream of the WSC gauging station near Caistor Corners). The runoff value, R, in the water balance calculation applies only to that portion of the Welland River watershed draining to the streamflow recorder.

Other techniques are available for estimating evapotranspiration when runoff data is not available. This has been applied site specifically by Gartner Lee (1987) to develop a water budget for the Preferred Site.

2.5.2 HYDROLOGIC MODELLING - SITE

2.5.2.1 General

The assessment and documentation of existing runoff patterns and quantities from the site provides a baseline against which post-development drainage patterns and quantities can be compared. It also provides the standard to which mitigation must be considered (i.e. post-development flows reduced to pre-development levels, and/or no significant adverse impacts downstream as a result of development of the site).

In this section of the report, the methodologies used to assess existing runoff conditions and the associated data requirements are described.

2.5.2.2 Model Selection

Ideally, estimates of peak flow rates along a watercourse should be based upon historical streamflow data measured at several locations within the area under study, or on an adjacent basin(s) with similar characteristics. However, neither the site swales nor the creeks within adjacent basins have been gauged in the past and therefore, no historical streamflow data is available for flow estimation purposes. To overcome this problem, hydrologic simulation procedures were used.

The Hydrologic Model (HYMO), since its development in the early 1970's by the U.S. Agricultural Research Service, has gained widespread use for flow calculation purposes in Ontario. In the absence of recorded flow data, it has been used for most of the flood plain mapping studies in the Province over the last 10 years. The application of the HYMO model to both undeveloped and developing areas has been improved recently by the University of Ottawa and has been designated the University of Ottawa Hydrologic Model (OTTHYMO). The HYMO/OTTHYMO model is capable of assessing the impact that development may have on runoff volume and peak flows from a given area. Therefore, this model has been selected for the assessment of existing runoff conditions and also for the assesment of the impacts that the landfill development may have on runoff volumes and peak flows.

The model responds to a design storm input (hyetograph) by producing an estimate of the time-history of runoff (hydrograph) as output. In general, hydrographs can be developed at any location within the watershed. In the case of the Preferred Site, they have been developed at all existing storm water outlets from the site.

The model employs the U.S. Soil Conservation Service (1985) methodology of generating excess rainfall. The runoff hydrographs are developed on the basis of parameters which describe the physical characteristics of the drainage areas. These include soil type, land use, and area size, length and slope. The program is also capable of routing computed hydrographs through channels (variable storage coefficient method) and through reservoirs (storage-indication method).

2.5.2.3 Model Data Requirements

The OTTHYMO model requires numerous watershed parameters as input in order to generate runoff estimates. These parameters, and the data upon which they were based are briefly described below:

i) Drainage Areas - OTTHYMO modelling requires the delineation of the drainage areas upstream from points where flow calculations are required. These upstream areas are referred to in the report as subwatersheds. All subwatershed delineations were based on 1:2000 scale, 0.5 metre (m) contour interval topographic mapping of the site.

ii) Runoff Curve Numbers - This input parameter is an indicator of the runoff potential from an area and is used to determine what percentage of rainfall actually becomes runoff for a given event.

Curve numbers for each subwatershed were derived by using available soils maps of the area (Canada Department of Agriculture and the Ontario Agricultural College, 1963), determining the hydrologic soil grouping (Ontario Ministry of Transportation and Communications, 1984) and by site visits to observe existing land uses.

iii) Initial Abstraction - Represents the rainfall volume at the outset of a storm which is taken up by wetting of the ground cover and depression storage, and does not occur as runoff volume. This parameter was estimated by reviewing available literature (University of Ottawa, 1983), and using 1:2000 scale, 0.5 m contour mapping.

iv) Time to Peak - Represents the time from the beginning of rainfall to the peak of the hydograph. This parameter is based on physical watershed characteristics such as length, slope and area. This data was obtained from 1:2000 scale, 0.5 m contour interval topographic mapping. Several methods, which are available for estimating times to peak, are presented in Appendix D.

v) Stage - Storage - Discharge Curves - This input is required to assess the impact of limited capacity culvert outlets on peak flows discharging from the site. Available upstream storage volumes were estimated from 1:2000 scale, 0.5 m contour interval topographic mapping, while culvert details and road profiles were obtained from a detailed field survey.

Input parameters and the rationale for their selection are described fully in Appendix D.

2.5.2.4 Model Output

On the basis of input data described above, the OTTHYMO model was used to develop 1:5, 1:10, 1:50 and 1:100 year flow estimates at all storm water outlets from the site. To provide a baseline against which post-development flow estimates can be compared, the model was also used to sum all of these individual subwatershed hydrographs to form a composite site hydrograph.

2.5.3 SUCKER CREEK HYDROLOGIC/HYDRAULIC ASSESSMENT

2.5.3.1 General

As shown on Figure 2.1, Sucker Creek drains lands located primarily to the north and east of the site. It is the only watercourse of significance in the site vicinity which could

potentially cause site flooding. To assess the potential for Sucker Creek to flood the site, a simple hydrologic/hydraulic analysis was carried out. The general procedures used and data requirements are described below. A detailed summary of the analysis, input data and results is given in Appendix E.

2.5.3.2 Hydrologic Analysis

The OTTHYMO watershed model was used to estimate flows at Silverdale Road, Highway 20 and Vaughan Road. These three locations were selected for analysis since the limited capacity of the culverts would be the most likely cause of site flooding. The data requirements of this model are the same as described under Section 2.5.2.3 and are not repeated here. In addition to the topographic mapping described previously, 1:10 000 scale (5 m contour interval) and 1:25 000 scale (10 ft. contour interval) maps were also used to delineate the Sucker Creek drainage basin. The available 1:2000 scale mapping was limited to the site and only a small portion of the site vicinity and did not cover the entire Sucker Creek drainage. This was not considered a serious limitation to the analysis.

2.5.3.3 Hydraulic Analysis

The flow estimates derived from the hydrologic analysis described above were used to estimate water surface elevations upstream from Silverdale Road, Highway 20 and Vaughan Road. Culvert details and top of road profiles were obtained from a detailed field survey. Stage-discharge curves for each culvert and road overflow were developed using inlet control nomographs (U.S. Bureau of Public Roads, 1963) and the standard weir flow equation as follows:

$$Q = CLH^{1.5}$$

where: Q = flow rate (m^3/s)
C = weir coefficient (1.66)
L = weir length (m)
H = head on weir (m)

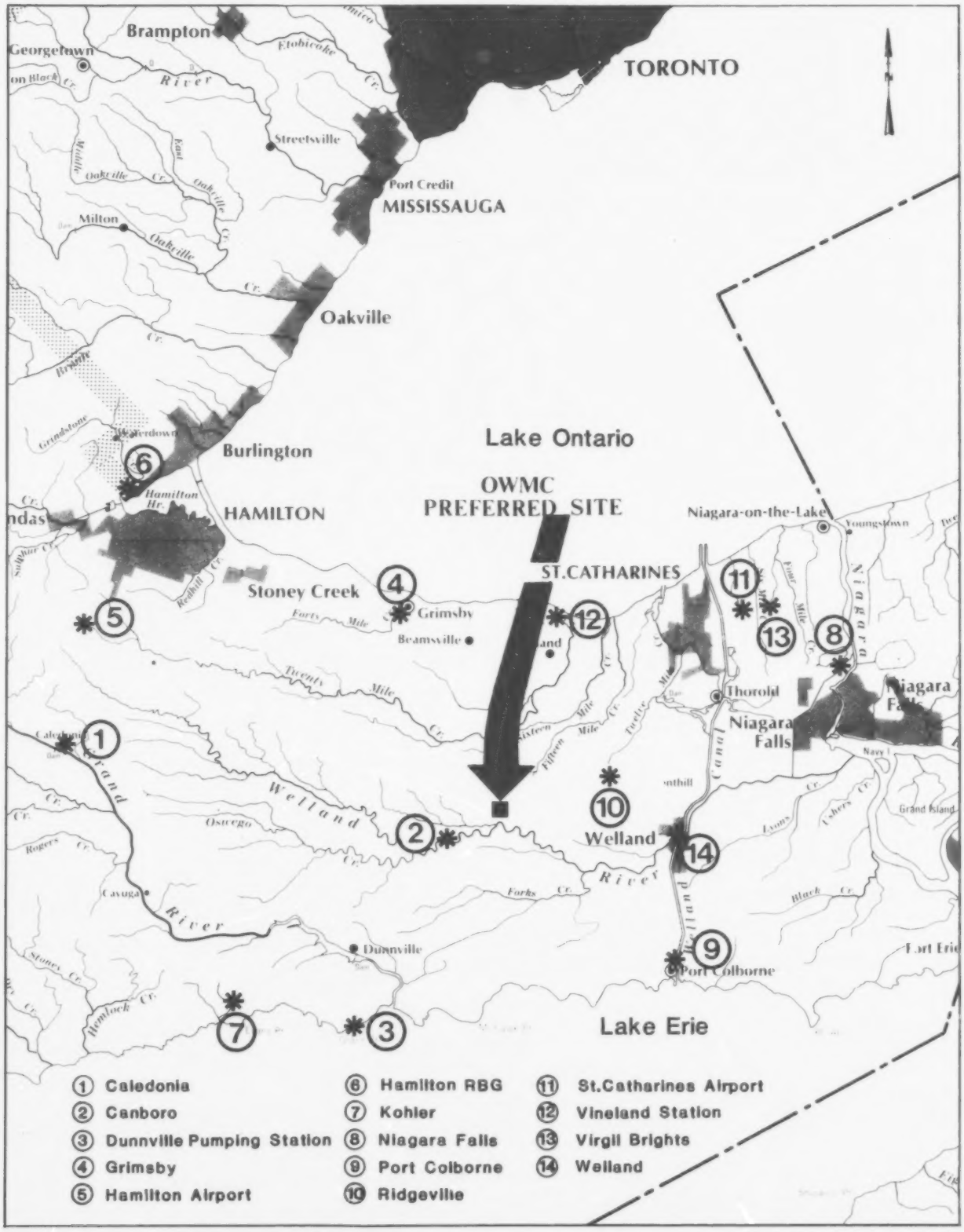
2.6 FORECASTING PROCEDURES

The OTTHYMO hydrologic model requires a single rainfall event (design storm) as input in order to generate a runoff hydrograph. Factors to be considered in the selection of this design storm include the following:

i) selection of meteorological data;
ii) selection of return period or historical storm upon which to base analysis and design;
iii) selection of an appropriate rainfall distribution.

The Atmospheric Environment Service (AES) records and statistically analyzes rainfall data at several stations in the vicinity of the site (see Figure 2.2). These stations were identified (Environment Canada, 1981a) and compared on the basis of number of years of record, proximity to the site, whether or not the gauge was continuously recording or manually read and the characteristics of the Intensity-Duration-Frequency (I-D-F) data (Environment Canada, 1984). On this basis, the Vineland Station gauge was selected as the most appropriate for use in this analysis.

For this study, flow calculations were carried out for the 1:5, 1:10, 1:50 and 1:100 year storm events as well as for the Regional Storm (Hurricane Hazel) as defined by the Ministry of Natural Resources (1986). It is anticipated that the landfill drainage system components will be designed on the basis of the 1:100 year return period storm. Thus it is considered prudent at this stage to calculate baseline condition flows for the same return period storm. Consideration was given to using Hurricane Hazel derived flows as a design basis. However, this event is considered too extreme for design of the landfill drainage



OWMC Ontario Waste Management Corporation

DILLON

10 5 0 10 20 Kilometres

CLIMATOLOGICAL STATION LOCATIONS

Figure 2.2

facilities (ditches, culverts, storm water pond, etc.). A Hurricane Hazel type of storm is generally used where failure of drainage facilities could result in catastrophic property damage and/or loss of life. Considering that the site is located in a predominantly rural area, and further, that failure or exceedance of the capacity of any of the drainage system components will not result in catastrophic loss downstream, the 1:100 year return period design storm is considered appropriate.

There are a number of design storm distributions currently being used for hydrologic modelling. However, most are based on U.S. rainfall data and/or on data averaged over a large region and several gauges. For this study, the Keifer and Chu distribution (American Society of Civil Engineers (ASCE), 1957) was selected since it is created directly from local rainfall data and not on the basis of composite or regional data. Using this method, the rainfall intensities for each design storm will closely follow the published AES Intensity-Duration-Frequency data (Environment Canada, 1984).

The design storms used in the hydrologic model were of 24 hour duration and separated (discretized) into 10 minute intervals. The 24 hour duration was selected because it exceeds the maximum time of concentration of the areas under study and also because it is most appropriate in the examination of storage effects. The 10 minute intervals were selected to ensure the peaks of the smaller sub-area hydrographs would not be missed. The sensitivity of peak flow estimates to a five minute interval was also analyzed. However, there was no significant change in peak flow estimates and the limitations of the model only allow a 16 hour storm to be used with five minute intervals. Therefore the use of a 24 hour duration storm with 10 minute intervals is considered appropriate.

The design storm data described above is summarized as follows:

i) Rainfall Gauge - AES Vineland Station
ii) Distribution - Keifer and Chu
iii) Duration - 24 hours
iv) Discretization Interval - 10 minutes
v) Return Periods - 1:5, 1:10, 1:50, 1:100 year and Regional Storm (for flow calculations)
vi) Return Period - 1:100 year (for design).

2.7 AGENCY AND PUBLIC CONTACTS

2.7.1 FORMAL PUBLIC CONTACTS

To date, the Phase 4B Surface Water Resources team has been involved in several public forums.

Public open houses were held in Smithville and Wellandport on 29 and 31 July, 1986 respectively at which times the surface water study team was represented. These forums gave the public the opportunity to talk directly to OWMC staff and their consultants representing the various technical disciplines for the Phase 4B studies. These open houses were designed to encourage public feedback on areas of concern respecting impacts on the local environment and community. Discussions with the public at these sessions tended to be wide ranging and in many instances appeared to be educational for the public.

2.7.2 AGENCY CONTACTS

The Surface Water Resources team has participated in several meetings with the Ministry of the Environment.

A number of contacts with other Provincial and Federal agencies have been held during the course of the study for data collection, information on policies and regulations and identification of areas of concerns for impact assessment. These contacts have included telephone calls, correspondence and/or meetings. A tabular summary of these agency contacts is provided in Appendix 'C'.

2.7.3 WATER USE SURVEY

Field interviews were conducted with landowners and tenants on-site and in the site vicinity during the Phase 4B studies. A similar task had been undertaken as part of the inter-site comparison in the Phase 4A investigation. This review was extended in Phase 4B to characterize the use of surface water resources on-site and in the site vicinity and to obtain specific information on flooding and drainage concerns.

The results of the Phase 4B surface water use survey (which was conducted by Gartner Lee Limited (1987) as a part of a larger survey comprising water well information) are summarized in Chapter 3.

2.8 WATER QUALITY REGULATIONS, GUIDELINES, OBJECTIVES AND CRITERIA

This study was conceived to meet the OWMC goals of:

- minimizing risk to human health,
- minimizing risk to the environment, and
- minimizing financial costs to OWMC and the people of Ontario.

In the context of this water quality study, the approach to these goals has been to consider the work of regulatory and advisory agencies. The work of these agencies has produced a variety of regulations, guidelines, objectives and criteria to consider in the development of an assessment of existing water quality. To the extent practical, a commentary has been provided on the parameters chosen for this study. The impact assessment is based on those regulations, guidelines, etc. The water quality concentrations given in the regulations, etc. were used in the development of this program, to define the scope of the monitoring and to set the detection levels at which the analytical work was carried out.

The collected recommendations of the several sources used for this study are given in Appendix G. The sources used reflect the goals of OWMC with an emphasis on drinking water use. The use of water by natural species, in agriculture and in recreational use was also considered. The list of sources used is as follows:

- Ontario Drinking Water Objectives (MOE, 1983).
- Water Management, Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment (MOE, 1984a).
- Guidelines for Canadian Drinking Water Quality, 1978, supplemented with information obtained in discussion with National Health and Welfare (HWC, 1980).
- Guidelines for Surface Water Quality and Water Quality Source Book (Environment Canada, 1979), supplemented with information obtained in discussion with Environment Canada (Taylor, 1986).
- International Joint Commission (IJC), Ambient Water Quality Guidelines, 1978 Great Lakes Water Quality Guidelines (IJC, 1985).
- USEPA recommendations on ingestion of contaminants in support of the prioritization of pollutants (USEPA, 1983b).

- USEPA Guidelines for Water Quality under Clean Water Act: (Treatability Manual Volume I, Treatability Data) (USEPA, 1983a).
- World Health Organization (WHO), Guidelines for Drinking Water Ouality (WHO, 1984).

The data summarized from these sources, as given in Appendix G, should not be compared in isolation with the observed concentrations. In most cases the chemistry must be considered, in particular, the behavior of the chemical as it travels in the environment to the receiver. Drinking water criteria are directed towards water ready for human consumption. Surface water in the study area would not be used for drinking without modern treatment.

The observed water quality also must be considered in terms of MOE policies for water management. The MOE has had specific policies (MOE, 1984a) for the use of surface water as a receiver of industrial discharge. These policies are aimed at maintaining water quality, where it is presently better than the provincial objectives, and upgrading or enhancing water quality that does not meet the objectives. These policies will be considered in reviewing the water quality data. More recently the MOE initiative, the Municipal-Industrial Strategy for Abatement (MISA) (MOE, 1986b), aims to mandate water quality assessment under prescribed methodologies as part of an overall effort to eliminate toxic discharges to surface waters.

Summary statements have been developed and are presented in this report (Appendix I) to give an overview of the rationale behind the collected guidelines and criteria for each parameter. These are meant to provide an understanding of the concern for each chemical. They focus on the most sensitive receptor but also discuss a broader range of environmental concerns.

Specific water quality criteria for the chemical parameters shown in Appendix G are grouped under the following broad 'receptor' categories:

- ambient water quality
- drinking water
- aquatic habitat
- agricultural
- recreational and aesthetic.

In all instances the criteria shown indicate a contaminant concentration limit or range within which the impact on the receptor is considered acceptable. Aquatic habitat receptors include fish and all waterborne organisms. Agricultural criteria generally govern the use of water for livestock watering or for irrigation purposes.

A review of the impact of chemical and bacteriological contaminants on the most susceptible receptor, and thus the receptor of greatest concern, is contained in Appendix I. Where possible, contaminants with similar characteristics and water quality impacts have been discussed as a group.

2.9 COMPARISON OF PHASE 4A AND 4B METHODS

2.9.1 INTRODUCTION

The Phase 4A surface water study was undertaken at a level of detail sufficient to enable a consistent comparison between the siting options. It was carried out primarily with secondary source information (available mapping, reports, background data, etc.). Limited field investigation was carried out and information was also obtained through questionnaires and meetings with local residents and citizen's groups.

The Phase 4B surface water study involves a more comprehensive analysis of surface drainage at the Preferred Site. This approach is consistent with proceeding at an increasing level of detail as the number of candidate sites is reduced.

A comparison of data sources and methodologies between the Phase 4A and 4B surface water studies is presented below. Comparison of the results between the Phase 4A and Phase 4B studies is briefly made in Section 3.4.3.

2.9.2 DATA SOURCES

For Phase 4A work, 1:10 000 scale (5 m contour interval) and 1:25 000 scale (10 ft. contour interval) topographic mapping were used in the delineation of watershed and subwatershed boundaries. This mapping was also used in the assessment of subwatershed parameters such as size, length, slope, etc. Phase 4B work used new 1:2000 scale (0.5 m contour interval) topographic mapping of the site and immediately adjacent areas. This mapping contains significantly more detail than the 1:10 000 and 1:25 000 scale mapping available during Phase 4A. This additional detail allowed for a more accurate delineation of watershed and subwatershed boundaries, prediction of flow paths and drainage patterns and assessment of required subwatershed parameters.

During the Phase 4A work, the sizes of local culverts were measured during site visits. For Phase 4B, this data base was improved by carrying out a detailed field survey of culverts and road profiles to geodetic datum. This provided an independent check of the 1:2000 scale mapping and also allowed the culverts to be tied into the new mapping.

2.9.3 METHODOLOGIES

Both of Phases 4A and 4B examined the flood susceptibility factor using the following three indicators:

i) runoff potential
ii) conveyance capacity
iii) designated flood plain lands and flood-prone areas.

The Phase 4A comparative assessment was carried out basically using qualitative means. The above indicators were used to characterize and compare the nature of the surface drainage systems at each of the candidate sites. Quantitative analyses were very simplistic (i.e. Rational Method for flow estimations), consistent with the level of detailed information available.

The Phase 4B assessment consisted of a more detailed quantitative analysis. Improved topographic mapping and detailed site survey allowed use of a more sophisticated hydrologic model (OTTHYMO) for the purpose of assessing runoff potential from the site. This increased detail also allowed an improved assessment of storage effects on peak flows discharging from the site.

The same methodology was used in Phases 4A and 4B for calculating culvert outlet capacities (inlet control nomographs). However, improved water surface elevations upstream from these culverts were obtained by incorporating the available storage and culvert capacities into the OTTHYMO reservoir routing routine.

The improved mapping and field survey available for Phase 4B also allowed for a hydrologic/hydraulic analysis to be carried out at selected locations along Sucker Creek (Silverdale Road, Highway 20 and Vaughan Road).

CHAPTER 3
EXISTING CONDITIONS

3.1 WELLAND RIVER WATERSHED

3.1.1 GENERAL FEATURES

The Welland River drainage is the largest of the rivers of the Niagara Peninsula with a total drainage area of approximately 880 km^2. The drainage boundary is shown on Figure 1.4. The Welland River has its headwaters in Ancaster and Glandford Townships near Mount Hope. From here the river winds eastward across the Haldimand clay plain, eventually discharging into the Chippawa Power Canal some 132 km from its source.

The average gradient of the Welland River is about 0.5 m/km over its entire length. The steepest gradient is in the upper third of the watershed. Over the last 70 km the stream bed falls about 3 m giving an average gradient of only 0.04 m/km. This very mild gradient leads to a sluggish river system which is characterized by a rather slow hydrologic response and considerable flood plain areas.

Land use in the Welland drainage basin is predominantly agricultural. The City of Welland is the major urban centre of the watershed. However, a number of small communities are located along the watercourse and include Wellandport, Attercliffe, Caistor Corners, Caistorville and Sinclairville.

3.1.2 PHYSIOGRAPHY

The majority of the Welland River drainage basin occupies the Haldimand clay plain. This clay plain lies generally between the Niagara escarpment and Lake Erie and is the major physiographic unit of the Niagara Peninsula. (Chapman and Putnam, 1984). The Haldimand clay plain exhibits very little surface relief. Drainage courses are poorly developed in many areas, including the vicinity of the Preferred Site.

The soils of the region tend to be of heavy texture and poorly drained. Caistor clay loam which is found in the Welland River drainage is an imperfectly drained soil often with swampy wet spots. To the east where the topography is more uniformly level, there is the heavy intractable soil called Welland clay (Chapman and Putnam, 1984).

The predominant soil on the Preferred Site is Haldimand clay loam.

3.1.3 CLIMATE

The Niagara Peninsula area lies within the 'Lake Erie Counties' and the 'Niagara Fruit Belt' climatic regions (Environment Canada, 1980). The boundary between these two regions lies along the Niagara Escarpment. The climates of these regions are modified by the influence of Lakes Erie and Ontario and to a lesser extent by the Niagara Escarpment. Generally, the climate of the Fruit Belt area is slightly more favourable than that of Lake Erie (Ontario Department of Energy and Resources Management, 1964). However, the Lake Erie area receives 10 to 15% more rainfall on average.

Climatic normals for two stations in the region are provided in Table 3.1 (Environment Canada, 1982). The Welland station data is typical of the 'Lake Erie Counties' area and is located centrally between Lake Erie and the top of the Escarpment. The station at Vineland Station is representative of the Fruit Belt area.

For the period of record, the extreme minimum temperatures at Welland for the months of December through March range from -27.8°C to -32.8°C. Comparable values at Vineland Station are -18.9°C to -25.6°C. However, it should be noted that the period of record for minimum temperatures is considerably longer at Welland (99 years) than at Vineland Station (54 years).

The annual average precipitation at Vineland is 817.4 mm (32.2 inches), compared to 938 mm (36.9 inches) at Welland.

Table 3.1 Climate Normals

VINELAND STATION 43° 11'N 79° 24'W 79 m	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR	CODE	
Daily Maximum Temperature	-0.7	0.0	4.3	11.4	17.7	23.5	26.5	25.5	21.6	15.3	8.5	2.2	13.0	1	Température Maximale Quotidienne
Daily Minimum Temperature	-7.5	-7.1	-2.9	2.3	7.2	13.2	16.5	16.0	12.4	6.7	1.7	-4.3	4.5	1	Température Minimale Quotidienne
Daily Temperature	**-4.1**	**-3.6**	**0.7**	**6.9**	**12.5**	**18.4**	**21.5**	**20.8**	**17.0**	**11.0**	**5.1**	**-1.0**	**8.8**	**1**	**Température Quotidienne**
Standard Deviation, Daily Temperature	2.2	2.2	1.8	1.5	1.6	1.1	1.1	1.2	1.3	1.6	1.5	2.1	0.6	1	Écart Type de la Température Quotidienne
Extreme Maximum Temperature	20.0	18.3	25.6	29.4	32.8	36.7	39.4	39.4	36.7	31.7	27.2	19.4	39.4		Température Maximale Extrême
Years of Record	54	54	54	54	53	53	54	54	54	55	55	55			Années de Relèves
Extreme Minimum Temperature	-23.3	-25.6	-18.9	-9.4	-2.2	1.7	6.7	4.4	-0.6	-6.7	-14.4	-26.0	-26.0		Température Minimale Extrême
Years of Record	54	54	54	54	53	54	54	54	54	55	55	55			Années de Relèves
Rainfall	27.9	27.9	49.9	66.9	66.4	71.0	61.8	85.9	74.6	58.2	57.5	44.1	692.1	1	Chutes de Pluie
Snowfall	35.3	27.9	20.7	5.5	T	0.0	0.0	0.0	0.0	0.6	6.4	29.0	125.4	1	Chutes de Neige
Total Precipitation	**63.2**	**55.8**	**70.6**	**72.4**	**66.4**	**71.0**	**61.8**	**85.9**	**74.6**	**58.8**	**63.8**	**73.1**	**817.4**	**1**	**Précipitations Totales**
Standard Deviation, Total Precipitation	24.5	27.3	34.3	22.4	29.7	24.4	26.5	47.4	42.7	37.0	24.2	25.6	110.9	1	Écart Type des Précipitations Totales
Greatest Rainfall in 24 hours	39.9	53.3	42.2	42.7	52.3	71.1	60.7	76.2	64.8	77.0	53.3	42.2	77.0		Chute de Pluie Record en 24 heures
Years of Record	53	54	54	54	53	54	54	54	54	55	55	55			Années de Relèves
Greatest Snowfall in 24 hours	38.1	33.0	25.7	23.6	T	0.0	0.0	0.0	0.0	6.4	19.1	66.0	66.0		Chute de Neige Record en 24 heures
Years of Record	54	54	53	54	53	54	54	54	54	55	55	55			Années de Relèves
Greatest Precipitation in 24 hours	39.9	53.3	42.2	43.9	52.3	71.1	60.7	76.2	64.8	77.0	53.3	66.0	77.0		Précipitation Record en 24 heures
Years of Record	53	54	53	54	53	54	54	54	54	55	55	55			Années de Relèves
Days with Rain	5	5	9	12	12	10	9	10	9	11	12	8	112	1	Jours de Pluie
Days with Snow	11	9	6	1	0	0	0	0	0	*	3	9	39	1	Jours de Neige
Days with Precipitation	15	13	13	13	12	10	9	10	9	11	13	15	143	1	Jours de Précipitation

WELLAND 43° 0'N 79° 16'W 175 m	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR	CODE	
Daily Maximum Temperature	-1.2	-0.5	4.7	12.4	18.9	24.3	26.8	25.8	21.7	15.6	8.4	1.8	13.2	1	Température Maximale Quotidienne
Daily Minimum Temperature	-8.5	-8.5	-3.8	1.8	7.4	13.2	16.1	15.6	11.8	6.0	1.1	-5.1	3.9	1	Température Minimale Quotidienne
Daily Temperature	**-4.9**	**-4.5**	**0.5**	**7.2**	**13.2**	**18.7**	**21.5**	**20.7**	**16.7**	**10.8**	**4.8**	**-1.7**	**8.6**	**1**	**Température Quotidienne**
Standard Deviation, Daily Temperature	2.4	2.4	2.2	1.5	1.6	1.2	1.1	1.2	1.4	1.7	1.6	2.2	0.6	1	Écart Type de la Température Quotidienne
Extreme Maximum Temperature	20.0	18.3	26.7	29.4	33.9	36.1	37.8	37.8	35.0	32.2	25.6	20.6	37.8		Température Maximale Extrême
Years of Record	99	98	101	99	100	99	98	97	98	99	102	99			Années de Relèves
Extreme Minimum Temperature	-32.8	-31.1	-27.8	-18.3	-6.1	1.1	3.9	2.8	-2.2	-8.9	-20.0	-27.8	-32.8		Température Minimale Extrême
Years of Record	99	98	101	99	100	99	98	97	99	99	102	99			Années de Relèves
Rainfall	33.0	28.6	57.9	72.7	71.5	72.2	61.1	91.2	85.5	70.2	67.0	50.0	760.9	2	Chutes de Pluie
Snowfall	50.0	39.6	26.7	4.8	T	0.0	0.0	0.0	0.0	0.6	12.9	42.4	177.0	2	Chutes de Neige
Total Precipitation	**83.0**	**68.2**	**84.6**	**77.5**	**71.6**	**72.2**	**61.1**	**91.2**	**85.5**	**70.8**	**79.9**	**92.4**	**936.0**	**2**	**Précipitations Totales**
Standard Deviation, Total Precipitation	32.7	33.3	29.3	24.8	31.9	35.3	28.9	39.7	46.7	45.9	29.8	21.6	86.9	2	Écart Type des Précipitations Totales
Greatest Rainfall in 24 hours	42.4	50.8	46.2	46.0	52.1	93.0	106.7	88.1	118.4	58.9	46.2	36.3	118.4		Chute de Pluie Record en 24 heures
Years of Record	93	92	92	96	95	97	96	92	94	96	97	95			Années de Relèves
Greatest Snowfall in 24 hours	78.7	61.0	81.3	43.2	13.0	0.0	0.0	0.0	0.0	20.3	33.0	50.8	81.3		Chute de Neige Record en 24 heures
Years of Record	85	88	91	92	96	97	99	97	98	98	95	94			Années de Relèves
Greatest Precipitation in 24 hours	78.7	61.0	81.3	55.9	52.1	93.0	106.7	88.1	118.4	58.9	49.3	50.8	118.4		Précipitation Record en 24 heures
Years of Record	86	88	89	91	96	98	97	93	95	96	96	94			Années de Relèves
Days with Rain	5	5	8	11	12	10	9	10	10	10	11	8	109	2	Jours de Pluie
Days with Snow	13	11	7	2	*	0	0	0	0	*	3	10	46	2	Jours de Neige
Days with Precipitation	17	14	14	13	12	10	9	10	10	10	14	17	150	2	Jours de Précipitation

SOURCE: CANADIAN CLIMATIC NORMALS 1951-1980, ENVIRONMENT CANADA

In Table 3.2 the average monthly precipitation for the two stations (1951 to 1980) is compared with the average monthly precipitation recorded in 1986.

TABLE 3.2
AVERAGE MONTHLY PRECIPITATION (mm)
WELLAND AND VINELAND STATIONS

Month	Welland 1951-1980	Welland 1986	Vineland Station 1951-1980	Vineland Station 1986
January	83.0	48.1	63.2	59.8
February	68.2	92.7	55.8	87.8
March	84.6	51.6	70.6	61.2
April	77.5	131.3	72.4	92.0
May	71.6	100.8	66.4	74.0
June	72.2	125.8	71.0	76.0
July	61.1	109.8	61.8	142.4
August	91.2	124.2	85.9	43.6
September	85.5	146.6	74.6	124.4
October	70.8	94.6	58.8	65.2
November	79.9	62.5	63.8	68.6
December	92.4	107.4	73.1	96.6
	938.0	1195.4	817.4	991.6

During 1986, a significant variability is evident in the monthly rainfall totals between the two stations. However, the trend to higher precipitation totals at Welland, than at Vineland, continued for the year.

Another significant statistic for 1986, is that total precipitation at Welland and Vineland Station exceeded normal annual precipitation by 27.4% and 21.3% respectively.

The rainfall hyetograph for Vineland Station from 1 January to the end of December 1986 is shown on Figure 3.1.

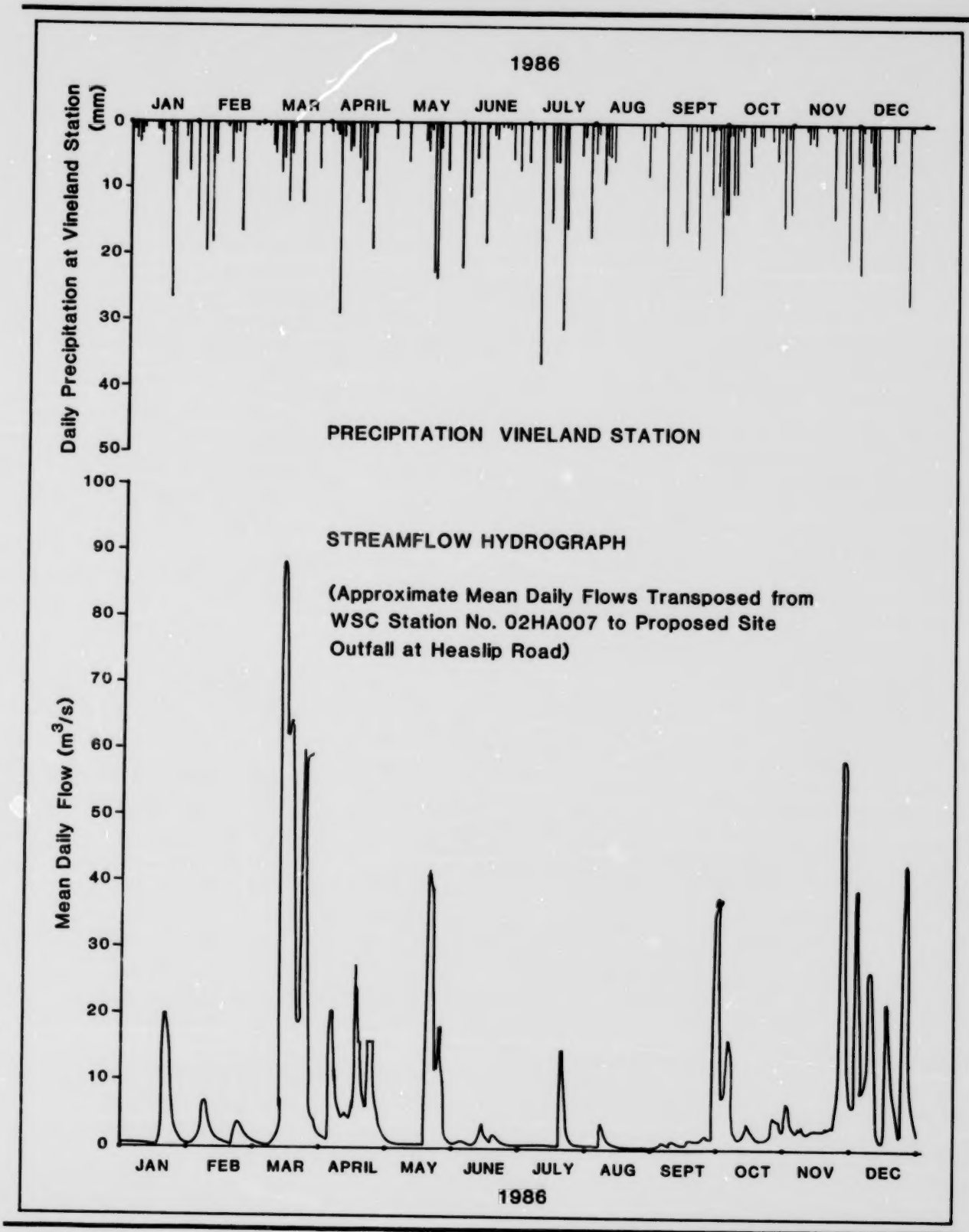
On-site, hourly precipitation data is available for the months of June to December 1986 inclusive as part of the atmospheric studies undertaken for OWMC (ORF,1987). The seven month precipitation total for the site is 493.5 mm, compared to 616.8 mm at Vineland Station and 770.9 mm at Welland.

3.1.4 LAND USE AND DISCHARGES INTO THE WELLAND RIVER

The Welland River watershed in the vicinity of the site and upstream is primarily an agricultural area. There are no large municipalities adjacent to the river, and no municipal sewage treatment plants discharge to the river (Pers. Communication - S. Irwin, 1986). Residences in the area are predominantly on septic tank systems.

There are no permitted industrial discharges to the river or to water bodies feeding it. At Glanford, the leachate from a municipal landfill site is collected and trucked to the Woodward Avenue sewage treatment plant. Landfill site drainage is collected in retention ponds, tested and periodically released to the river if storm water quality is acceptable. The Welland River also receives effluent from a sewage lagoon servicing the Oswego Park subdivision. This discharge is only permitted once or twice per year during high flow periods. (Pers. Communication - J.V. Viirland, 1987.)

Other discharges to the river would include field runoff containing fertilizers and pesticides, animal waste drainage, and possibly effluent from residential septic systems. Fertilizers could contribute to trace metals as well as to major nutrient species.



OWMC Ontario Waste Management Corporation

DILLON

WELLAND RIVER STREAMFLOW – 1986

Figure 3.1

3.2 WELLAND RIVER DRAINAGE

3.2.1 BACKGROUND

The Welland River meanders over a course of 132 km from the headwaters near Mount Hope to the outlet near Chippawa. This river system is one of the most complex in Ontario. The complexity of the system is attributable mainly to the mild channel gradient, the numerous structures crossing the river, the two inverted syphons required to convey the river beneath the old and new Welland Canals and the operation of Ontario Hydro's Niagara Generating Station. All of these factors may influence water levels near the site now and/or in the future. Accordingly, each of these features has been considered in relation to its influence on water levels and the suitability of the Welland River for use by OWMC for water supply and for storm water discharge.

Each of these factors and the effect they may have on Welland River flows and water levels is discussed below.

3.2.2 FACTORS AFFECTING FLOWS AND WATER LEVELS IN THE WELLAND RIVER

3.2.2.1 Mild Channel Gradient

The main branch of the Welland River has a longitudinal slope of approximately 0.04 m/km from above the Village of Attercliffe to its point of discharge into the Chippawa Power Canal (a distance of over 70 km). This very mild channel slope, in combination with a mean Niagara River water surface elevation of 171.0 m $\pm$, creates a ponding condition along this lower 70 km reach, even when there is no significant flow in the river. Thus, under low flow

conditions, the existing Welland River gradient will allow Niagara River water level fluctuations to cause corresponding fluctuations in Welland River water levels near the site. The recently completed Welland River Study (Dillon, 1985) indicates that the existing mild channel gradient is not likely to be altered in the future since dredging and/or channelization would either be ineffective in controlling flooding or too expensive.

3.2.2.2 Bridges

A total of 13 bridges span the Welland River between Wellandport and the Chippawa Power Power Canal outlet. Most of these bridges are supported by piers and abutments which extend well into the flood plain. The recently completed hydraulic analysis for the Niagara Peninsula Conservation Authority (Dillon, 1985) indicated that even under Regional Storm flow conditions, the cumulative effect of these structures on water levels near the site is not significant.

This report also recommends that any new bridges to be constructed in the future be built to have minimal effect on Welland River water levels for even 1:100 year and Regional Storm flows. Therefore, existing bridges exert little influence over water levels near the site now and this is not expected to change if new river crossings are constructed in the future.

3.2.2.3 Syphons

Old Syphon. The original Welland River syphon was constructed beneath the Welland Canal by the St. Lawrence Seaway Authority during the period from 1925 to 1930. This multi-barrelled, inverted syphon was designed to provide a greater canal depth to accommodate heavier water traffic.

The old structure is located in the City of Welland, north of Main Street and approximately 26 km downstream from the site. It consists of six 6.7 m (22 ft.) diameter tubes in parallel beneath the canal, connected at each end to six vertical shafts which rise to the river bed.

The syphon headwall on each side of the canal is 5.5 m (18 ft.) thick. The massive concrete structure is lightly reinforced and supported on timber piles driven to rock.

In 1969, the City of Welland used the southern most tube to route three sanitary sewers across the canal. These sewers were encased in concrete, reducing the area of flow in this tube. The total available cross sectional area of the syphon tubes, assuming no other blockages, is about 207 m^2 (2,230 $ft.^2$).

Both the inlet and outlet of the syphon are always submerged by the backwater pool from the Niagara River. A review of the "as built" drawings of the syphon indicates no apparent constriction in the hydraulic path through the syphon.

The syphon functions as a sag culvert with outlet control.

Aside from the man-made concrete sewer casement, the syphon has probably been modified naturally by the river flow regime and become a part of the river. It is likely that long-term silt accumulation has occurred to some degree within the syphon barrels. During 1982 field investigations, depths of silt within the syphon barrels were found to range between 0 and 1.8 m. Silt and debris depths of up to 1.8 m were also measured in the old syphon during exploratory work by divers in 1967.

New Syphon. A new syphon was constructed on the Welland River by the St. Lawrence Seaway Authority in 1973. The new syphon, located near Port Robinson (and approximately 32 km downstream from the site), conveys the Welland River under the new ship canal, east of the City of Welland.

The new syphon consists of four 5.2 m x 8 m (17.3 ft. x 26.3 ft.) rectangular barrels in parallel. The flared inlet and outlet of each of the syphon barrels are constructed on a slope of approximately 2.4:1, giving better inlet/outlet conditions compared to the old culvert. The new syphon is similar to the old in that it functions as a sag culvert with both the inlet and outlet always being submerged by the backwater pool from the Niagara River.

The total available cross-section area of the new syphon, assuming no blockages, is approximately 169 m^2 (1,820 $ft.^2$).

The new syphon has approximately 75% excess capacity for a constant head differential compared to the old syphon. Thus, the new structure is more efficient than the old.

The maximum head loss estimated by high water marks during the 1979 spring runoff event was 0.15 m (0.5 ft.) at the old syphon and 0.09 m (0.3 ft.) at the new syphon.

A hydraulic analysis of the syphons in the Welland River Study (Dillon, 1985) indicates a combined headloss through both syphons of approximately .5 m for the 1:100 year flow. This assumes all syphon barrels are free from silt build-up. It is expected that silt builds up in the syphon barrels during periods of low flow but is washed away during higher flows.

It appears that under existing conditions the syphons may have a minor impact on Welland River water levels near the site by causing a slight increase during periods of very high flow. However, the Welland River Study concluded that improvement or even removal of the syphons would not yield a significant increase in hydraulic efficiency especially in light of the very high cost.

Thus, for this study, it can be assumed that the existing syphon configuration and efficiencies will not change in future and hence water levels near the site will not be significantly affected.

The effect on Welland River water levels of removing all bridges and both syphons from the Welland River flood plain was examined in the Welland River Study. It was concluded that a 1:100 year water level reduction of only 0.3 m would be achieved near the site. Consequently, downstream structural improvements in the future are not expected to affect the suitability (in terms of water availability) of the Welland River for water supply or storm water discharge.

3.2.2.4 Ontario Hydro Niagara River Regulation

The final factor which may influence Welland River water levels now and in the future is the operation of the Ontario Hydro Niagara Generating Stations.

Prior to the early 1920's, the Niagara River provided the natural outlet for runoff from the very mild sloping Welland River watershed. However, as part of the Sir Adam Beck - Niagara Generating Stations facility, the last 6 km of the Welland River were dredged and the flow direction reversed. This formed the

initial portion of the generating station intake which diverted flow from the Niagara River. This flow reversal and diversion were accomplished by constructing the long Queenston-Chippawa Power Canal north from the Welland River, then northeast through the City of Niagara Falls to the power plant forebay.

Whereas the Welland River discharged directly to the Niagara River above the Falls prior to the early 1920's, the river was subsequently diverted through the Queenston-Chippawa Power Canal and ultimately through the Sir Adam Beck Generating Station discharging to the Niagara River below the Falls. Further details concerning development of the Ontario Hydro Niagara Generating Stations and historical regulation as they affect water levels are given in Appendix F.

To determine whether or not the Welland River is capable of providing the site with an adequate supply of water (volume), the all-time low water surface elevation at the Montrose gauge (at the confluence of Welland River and Chippawa Power Canal) was obtained from Ontario Hydro. Over the 60 year period of record at the Montrose gauge, the lowest instantaneous water surface elevation of 169.8 m occurred on 30 January 1939. If this water surface elevation is projected horizontally from Montrose upstream to the site, a minimum water depth of about 1.6 m results at the proposed intake location (Welland River invert = 168.2 m).

This can be considered a conservatively low estimate of water level because:

i) some flow and therefore some headloss between Montrose and the site is likely to occur along the Welland River during most of the year;

ii) this all-time low Montrose level occurred prior to construction of the gated control structure which now exists part-way across the Niagara River. This structure serves to moderate extremely high and low levels which occurred previously on the Niagara River;

iii) the International Niagara Board of Control (INBC, 1973) directive, which requires levels to be maintained between 171.8 m and 170.6 m even under extreme (high or low flow and ice jam) conditions.

On average, the depth of water at the proposed water supply intake location is estimated to be 2.4 to 2.7 m based on a long-term mean water surface elevation at Montrose of 170.9 m El. The all-time minimum depth during the 60 years of record is estimated to be 1.6 m. Therefore, an adequate supply of water will be available to the OWMC facility for all normal Ontario Hydro operating conditions. This assumes of course that the water intake can be kept free of silt, debris and ice.

The Welland River Study (Dillon, 1985) concluded that Ontario Hydro operations do have some effect on water levels in the vicinity of the site (more so under low flow conditions than high flows). However, no degree of operational change would be effective in eliminating flooding problems along the river through West Lincoln and Wainfleet Townships (in the vicinity of the site). Under normal Ontario Hydro operations at the mouth of the Welland River, the reliability of water supply for the treatment facility will not be affected, now or in the future. Ontario Hydro has confirmed that the same holds true under maintenance or emergency conditions (Ontario Hydro, 1986).

3.2.3 STREAMFLOW

Monthly and annual mean discharges for the Welland River below Caistor Corners (WSC Station No. 02HA007) are shown in Table 3.3 for the period of record from 1957 to 1985. Annual extremes and annual total discharge from 1958 to 1985 are summarized in Table 3.4. Prior to 1969, the gauging station only measured daily flows rather than providing a continuous record. Consequently, no maximum instantaneous discharges are available prior to 1969.

Table 3.5 provides the daily flow record for the Caistor Corners station for 1986.

The highest peak instantaneous flow measured since 1969 at Station 02HA007 is 74.4 m^3/s on 14 February 1984. A maximum daily discharge of 96.3 m^3/s was measured in March 1959 and is the extreme for the entire period of record. Based on the average ratio of the maximum instantaneous flow/maximum daily flow, this suggests a peak instantaneous flow of approximately 104 m^3/s.

Figure 3.2 depicts the long-term average mean monthly flows for the Welland River below Caistor Corners. This is compared with the mean monthly flows which occurred during 1986.

The average mean monthly flows are indicative of average monthly runoff volume in the Welland River over a typical year. The flow regime is characterized by highest runoff during the spring freshet, dropping to a minimum in the month of July. Typically, streamflow increases steadily in late summer and through the fall, reaching a lower peak (i.e. lower than March) in December before the deep winter freeze-up.

WATER SURVEY OF CANADA
AUG 1 1986 PAGE 391
GUELPH, ONT

WELLAND RIVER BELOW CAISTOR CORNERS

STATION NO. 02HA007

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC METRES PER SECOND FOR THE PERIOD OF RECORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1957	---	---	---	---	---	---	0.690	0.005	0.015	0.012	0.035	2.25	---	1957
1958	0.135	0.722	7.43	1.37	0.072	0.014	0.004	0	0.001	0.003	0.117	0.119	0.838	1958
1959	3.27	3.47	18.8	7.35	0.395	0.101	0	0	0	0.209	1.02	2.94	3.14	1959
1960	2.21	2.98	2.04	13.3	3.81	0.286	0.022	0.046	0.001	0	0.016	0.006	2.04	1960
1961	0.003	3.97	1.33	5.04	0.700	0.073	0.022	0.414	0.161	0.004	0.107	0.315	0.984	1961
1962	1.10	0.320	8.44	0.547	---	---	---	---	---	6.00	5.23	2.86	---	1962
1963	0.042	0.021	11.1	2.49	0.852	0.373	0.001	0.175	0.005	0	0.018	0.036	1.27	1963
1964	1.51	0.141	8.53	3.81	0.826	0.606	0.137	1.24	0.082	0.010	0.019	0.989	1.45	1964
1965	2.13	7.20	4.20	7.50	0.208	0.005	0.004	0.008	0.023	0.304	1.87	3.54	2.21	1965
1966	1.11	4.52	8.02	2.35	0.719	0.068	0.001	0	0	0	0.012	3.70	1.70	1966
1967	2.41	1.70	5.86	3.66	2.63	0.088	0.012	0.001	0.003	0.151	0.732	3.82	1.76	1967
1968	1.38	6.61	5.45	0.885	0.401	2.67	0.190	0.008	0.402	0.083	5.35	2.80	2.14	1968
1969	5.35	3.45	3.26	7.62	3.77	0.240	0.027	0.040	0	0	0.159	1.21	2.08	1969
1970	0.155	2.07	5.46	2.93	0.263	0.030	0.106	0.027	0.053	0.351	2.65	4.55	1.55	1970
1971	0.565	4.01	8.57	1.84	0.114	0.265	0.002	0	0	0.006	0.609	1.36	1.38	1971
1972	3.50	0.092	14.1	7.22	1.68	0.354	0.153	1.12	0.107	0.440	3.77	8.88	3.48	1972
1973	4.81	2.22	11.1	3.12	0.911	0.196	0.138	0.133	0.192	0.438	6.31	5.83	3.05	1973
1974	8.13	5.65	5.64	3.83	6.23	0.744	0.083	0.073	0.191	0.241	0.657	1.88	2.77	1974
1975	2.65	4.62	6.06	1.73	0.383	0.787	0.038	0.238	1.60	0.755	1.61	3.76	2.00	1975
1976	2.98	12.2	9.86	5.99	4.19	0.289	0.328	0.229	0.091	0.254	0.463	0.473	3.08	1976
1977	0.152	0.754	8.75	2.48	0.061	0.178	0.647	0.463	7.71	3.56	1.73	12.8	3.29	1977
1978	1.92	1.89	10.8	5.67	0.566	0.131	0.436	0.512	0.693	2.55	0.764	2.37	2.36	19[illegible]
1979	4.39	2.14	7.11	8.25	0.524	0.068	0.064	0.081	0.349	0.583	2.28	6.18	2.67	19[illegible]
1980	0.885	0.535	5.41	6.40	0.686	0.252	0.391	0.307	0.676	1.32	0.631	1.99	1.63	1980
1981	0.376	11.5	0.872	1.18	0.730	0.875	0.648	1.94	4.10	3.22	2.34	2.91	2.46	1981
1982	3.47	0.135	12.0	5.72	0.211	2.09	0.086	0.145	0.611	0.622	5.51	8.27	3.26	1982
1983	1.99	3.93	4.41	4.43	3.86	0.604	0.509	1.89	0.622	0.906	3.45	6.78	2.78	1983
1984	0.632	9.40	9.05	9.26	2.12	4.66	0.133	0.099	1.85	0.643	1.80	4.35	3.63	1984
1985	1.97	6.53	8.80	4.08	0.122	0.118	0.048	0.219	0.193	1.80	13.7	3.72	3.41	1985
MEAN	2.39	3.67	7.59	4.64	1.37	0.576	0.176	0.336	0.705	0.844	2.15	3.51	2.31	MEAN

LOCATION - LAT 43 01 30 N
LONG 79 37 00 W

DRAINAGE AREA, 230 KM2
REGULATED

Stream Flow Summary - Welland River
Table 3.3

WATER SURVEY OF CANADA
AUG 1 1986 PAGE 382
GUELPH, ONT

WELLAND RIVER BELOW CAISTOR CORNERS

STATION NO. 02HA007

ANNUAL EXTREMES OF DISCHARGE AND ANNUAL TOTAL DISCHARGE FOR THE PERIOD OF RECORD

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (M3/S)	MAXIMUM DAILY DISCHARGE (M3/S)	MINIMUM DAILY DISCHARGE (M3/S)	TOTAL DISCHARGE (DAM3)	YEAR
1958	---	20.7 ON MAR 2	0 ON JUL 18 *	26 400	1958
1959	---	96.3E ON MAR 21 *	0 ON JUN 19	98 900	1959
1960	---	79.08 ON APR 1	0 B ON MAR 9	64 400	1960
1961	---	45.9 ON FEB 26	0 B ON JAN 21	31 100	1961
1962	---	51.5E ON NOV 11	---	---	1962
1963	---	45.38 ON MAR 18	0 ON JUL 7	40 100	1963
1964	---	31.4 ON MAR 15	0 ON JUN 23	46 000	1964
1965	---	56.68 ON FEB 11	0 ON JUN 28	69 500	1965
1966	---	33.48 ON FEB 12	0 ON JUL 9	53 500	1966
1967	---	33.4 ON DEC 22	0 ON JUN 26	55 600	1967
1968	---	45.38 ON FEB 3	0 B ON JAN 15	67 600	1968
1969	56.4 AT 17:00 EST ON JAN 31	52.7 ON JAN 31	0 ON AUG 16	65 600	1969
1970	29.4 AT 18:46 EST ON DEC 4	24.5 ON APR 3	0.0068 ON JAN 26	48 900	197.
1971	---	48.18 ON FEB 28	0 ON JUL 15	43 600	1971
1972	31.1 AT 01:05 EST ON DEC 7	27.1 ON APR 17	0.023B ON FEB 13	110 000	1972
1973	53.2 AT 10:31 EST ON DEC 28	51.0 ON DEC 28	0.093 ON JUN 21	96 300	1973
1974	44.2 AT 05:52 EST ON FEB 23	41.6 ON FEB 23	0.027 ON JUL 17	87 500	1974
1975	---	35.48 ON FEB 25	0.014 ON JUL 7	63 200	1975
1976	67.4 AT 02:30 EST ON MAR 6	61.7 ON MAR 6	0.022 ON JUN 14	97 400	1976
1977	47.9 AT 09:02 EST ON DEC 16	47.0 ON DEC 16	0.011 ON MAY 30	104 000	1977
1978	---	49.18 ON MAR 22	0.031 ON JUN 6	74 600	1978
1979	53.6 AT 01:46 EST ON DEC 26	49.3 ON DEC 26	0.039 ON JUL 24	84 300	1979
1980	49.9 AT 00:33 EST ON MAR 22	43.6 ON MAR 22	0.016 ON JUL 21	51 400	1980
1981	36.9 AT 23:30 EST ON FEB 17	33.08 ON FEB 18	0.020 ON JUL 18	77 600	1981
1982	42.8 AT 00:16 EST ON DEC 26	40.08 ON MAR 15	0.034 ON MAY 22	103 000	1982
1983	38.4 AT 06:15 EST ON DEC 13	35.5 ON DEC 13	0.067 ON JUL 14	57 600	1983
1984	74.4 AT 14:30 EST ON FEB 14 *	73.5A ON FEB 14	0.071 ON AUG 21	115 000	1984
1985	---	50.88 ON FEB 25	0.001 ON AUG 3	107 000	1985
				73 000	MEAN

A - MANUAL GAUGE (SEE REFERENCE INDEX)
B - ICE CONDITIONS
E - ESTIMATED
* - EXTREME RECORDED FOR THE PERIOD OF RECORD

Annual Extremes and Total Annual Discharge - Welland River

Table 3.4

WATER SURVEY OF CANADA
JUN 10 1987 PAGE 219
GUELPH, ONT.

WELLAND RIVER BELOW CAISTOR CORNERS

STATION NO. 02HA007

DAILY DISCHARGE IN CUBIC METRES PER SECOND FOR 1986

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	0.180B	0.110B	0.360B	0.866	0.253	0.189	0.114	0.327	0.093	19.6	1.42	2.99	1
2	0.170B	0.130B	0.280B	0.730	0.171	0.286	0.112	0.325	0.097	8.47	3.14	3.44	2
3	0.160B	0.180B	0.275B	0.665	0.131	0.486	0.104	0.229A	0.098	3.91	3.96	15.5	3
4	0.150B	0.370B	0.270B	0.622	0.115	0.479	0.103	0.194E	0.120	4.61	3.06	19.7	4
5	0.150B	2.00 B	0.280B	0.754	0.104	0.413	0.101	0.133E	0.429	6.38	2.26	10.6	5
6	0.145B	3.50 B	0.320B	9.60	0.096	0.310	0.095	0.122A	0.532	7.04	1.70	5.38	6
7	0.143B	2.60 B	0.400B	10.4	0.095	0.247	0.091	0.183	0.453	3.78	1.38	4.06	7
8	0.142B	1.75 B	0.480B	4.50	0.082	0.236	0.088	1.76	0.400	2.38	1.33	4.21 B	8
9	0.130B	1.40 B	0.600B	3.18	0.077	0.254	0.067	1.87	0.366	1.51	1.69	6.00	9
10	0.125B	1.00 B	0.726B	2.43	0.068	0.215	0.088	1.04	0.436	1.10	1.48	13.6	10
11	0.120B	0.800B	44.1	2.45	0.059	0.184	0.090	0.697	0.673	0.897	1.533	13.1	11
12	0.113B	0.560B	43.3	2.72	0.059	0.430	0.119	0.459	0.623	0.821	1.669	6.70	12
13	0.108B	0.460B	31.7	2.68	0.062	1.19	0.137	0.367	0.359	1.05	1.498	2.33 B	13
14	0.104B	0.300B	32.0	2.23	0.071	1.71	0.141	0.261	0.199	1.33	1.309	0.666B	14
15	0.102B	0.240B	26.7	2.32	0.080	0.854	0.140	0.195	0.190	1.72	1.373	0.555B	15
16	0.100B	0.200B	19.6	6.48	0.093	0.615	0.140	0.159	0.294	1.94	1.52	0.505	16
17	0.130B	0.182B	12.5	13.6	0.092	0.873	0.145	0.137	0.220	1.33	1.58	0.482	17
18	0.700B	0.140B	8.97	7.63	0.091	1.07	0.252	0.116	0.291	1.05	1.54	2.67	18
19	3.00 B	0.160B	24.2	3.59	1.53	0.788	1.53	0.101	0.451	0.866	1.52	11.1	19
20	10.1 B	0.300B	29.7	2.88	20.7	0.464	7.33	0.096	0.746	0.791	1.453	7.50	20
21	9.60 B	0.600B	9.59	7.97	19.4	0.291	6.18	0.08E	0.737	0.752	1.593	4.00 B	21
22	4.80 B	1.20 B	4.70	7.83	6.73	0.215	2.43	0.064	0.688	0.714	1.558	2.50 B	22
23	3.00 B	1.70 B	3.04	3.93	5.66	0.179	0.772	0.084	0.737	0.539	1.779	1.60 B	23
24	2.00 B	2.00 B	2.37	2.73	9.12	0.148	0.360	0.068	0.912	0.605	3.49	1.05 B	24
25	1.20 B	1.45 B	2.08	2.17	5.71	0.136	0.220	0.048	1.10	0.860	5.69	15.3	25
26	0.800B	1.05 B	2.13	1.52	2.79	0.121	0.164	0.041	0.973	0.744	9.95	21.5	26
27	0.500B	0.800B	2.54	0.836	1.33	0.115	0.129	0.046	0.817	1.12	29.3	7.02	27
28	0.350B	0.600B	2.92	0.656	0.550	0.120	0.114	0.062	0.756	2.33	19.6	3.49	28
29	0.220B		2.14	0.591	0.329	0.119	0.107	0.079	3.45	2.55	5.00	2.39	29
30	0.150B		1.47	0.414	0.224	0.119	0.109	0.067	19.2	2.02	3.89	1.73	30
31	0.130B		1.09		0.173		0.106	0.084		1.37		1.35	31
TOTAL	38.830	25.782	310.831	108.974	75.045	12.856	21.716	9.542	36.440	86.219	119.03	193.538	TOTAL
MEAN	1.25	0.921	10.0	3.63	2.45	0.429	0.701	0.308	1.21	2.78	3.37	6.24	MEAN
MAX	10.1	3.50	44.1	13.6	20.7	1.71	7.33	1.87	19.2	19.6	29.3	21.5	MAX
MIN	0.100	0.110	0.270	0.414	0.059	0.115	0.067	0.041	0.093	0.539	1.30	0.482	MIN

DISCHARGES IN CUBIC METRES PER SECOND

MEAN, 2.85
MAXIMUM DAILY, 44.1 ON MAR 11
MINIMUM DAILY, 0.041 ON AUG 26
MAXIMUM INSTANTANEOUS,
47.7 AT 02:44 EST ON MAR 12

SUMMARY FOR THE YEAR 1986

TYPE OF GAUGE - RECORDING
LOCATION - LAT 43 01 30 N
LONG 79 37 00 W
DRAINAGE AREA, 230 KM2
A - MANUAL GAUGE
B - ICE CONDITIONS
E - ESTIMATED
REGULATED

MONTHLY TOTAL DISCHARGE
IN CUBIC DECAMETRES

JAN	3 350	JUL	1 860
FEB	2 230	AUG	824
MAR	26 900	SEP	3 150
APR	9 420	OCT	7 450
MAY	6 570	NOV	10 300
JUN	1 110	DEC	16 700

TOTAL DISCHARGE, 89 900 DAM3

1986 Stream Flow Data - Welland River
Table 3.5

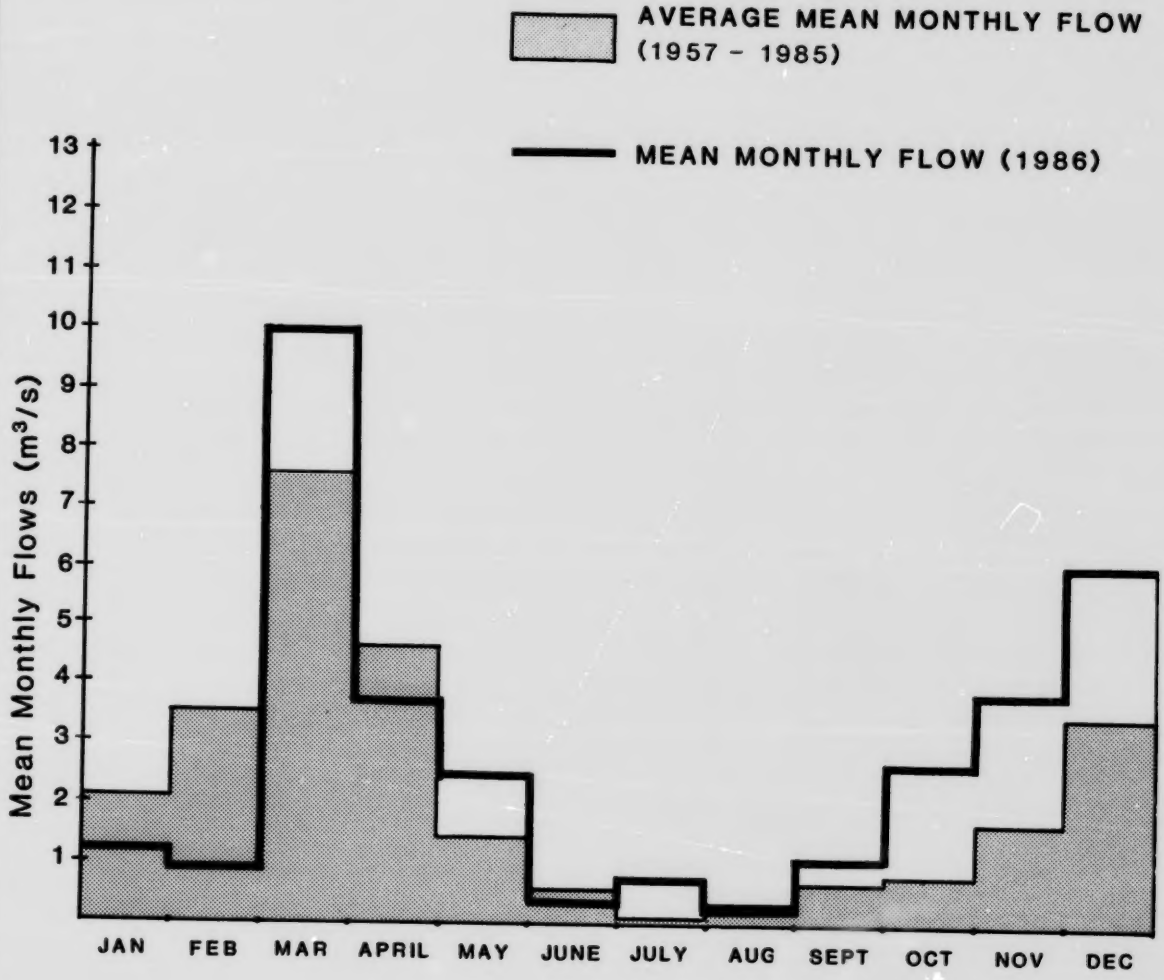
Figure 3.2 demonstrates that the 1986 flow regime, while typical in its general shape, tended to more extreme values during the fall and winter months. For example, runoff during January and February was well below normal, while the mean monthly flow for March (10.0 m^3/s) considerably exceeded the long-term average. Nevertheless, the peak daily flow (44.1 m^3/s) during March (representing the annual daily extreme for 1986) was not exceptionally high. This maximum daily flow has been equalled or exceeded in 16 out of 28 years for which records are available.

The high average runoff during March of 1986 appears to be indicative of a generally cold winter, with near normal precipitation, providing an above average snowpack accumulation. The melt period in mid-March released the water bound up in the snow. The spring melt of 1986 was also accompanied by several days of light to moderate rainfall.

During 1986, the mean monthly flow bottomed out in the months of June and August at 0.43 m^3/s and 0.31 m^3/s respectively, only slightly below the long-term averages of 0.58 m^3/s and 0.34 m^3/s. In between, the month of July was exceptionally wet with the mean monthly flow at Caistor Corners of 0.70 m^3/s. This well exceeded the average mean July runoff of 0.18 m^3/s and is the highest average runoff for July in the 29 years of record at the Caistor Corners streamflow station.

Low flows in the Welland River at Caistor Corners fall to zero or near zero on an annual basis. These typically occur during mid-winter periods of severe cold and/or during extended summer dry periods.

Above average precipitation in the late summer and early fall of 1986 led to above average runoff throughout the fall months.



SOURCE: WATER SURVEY OF CANADA 1986, WELLAND RIVER BELOW CAISTOR CORNERS, STATION No.02HA007

OWMC Ontario Waste Management Corporation

DILLON

WELLAND RIVER MEAN MONTHLY FLOW

Figure 3.2

Figure 3.1 displays the estimated daily flows for 1986 in the Welland River near the Preferred Site, together with recorded precipitation at Vineland Station. The flows have been transposed from the WSC Station No. 02HA007 below Caistor Corners using a factor of 2 (refer to Section 2.5.1.1).

Peak flows for a range of design storm events were calculated as part of the flood plain mapping study for the Niagara Peninsula Conservation Authority (Dillon, 1985). Flows were computed at various points along the Welland River for a range of design storms with return periods of 5, 10, 25, 50 and 100 years, as well as the Regional Storm (Hurricane Hazel). Of relevance to this study are peak flows computed at Port Davidson (approximately 11 km upstream from Wellandport) and at Beckett's Bridge (approximately 3.5 km downstream from the Pearson Bridge). These flows are summarized in Table 3.6. The flow at Beckett's Bridge are considered more typical of those in the reach in proximity to the Preferred Site. The flows at Port Davidson do not include the significant contributions from Oswego Creek and, of lesser significance, from Beaver Creek.

TABLE 3.6
SUMMARY OF PEAK FLOWS (m^3/s)

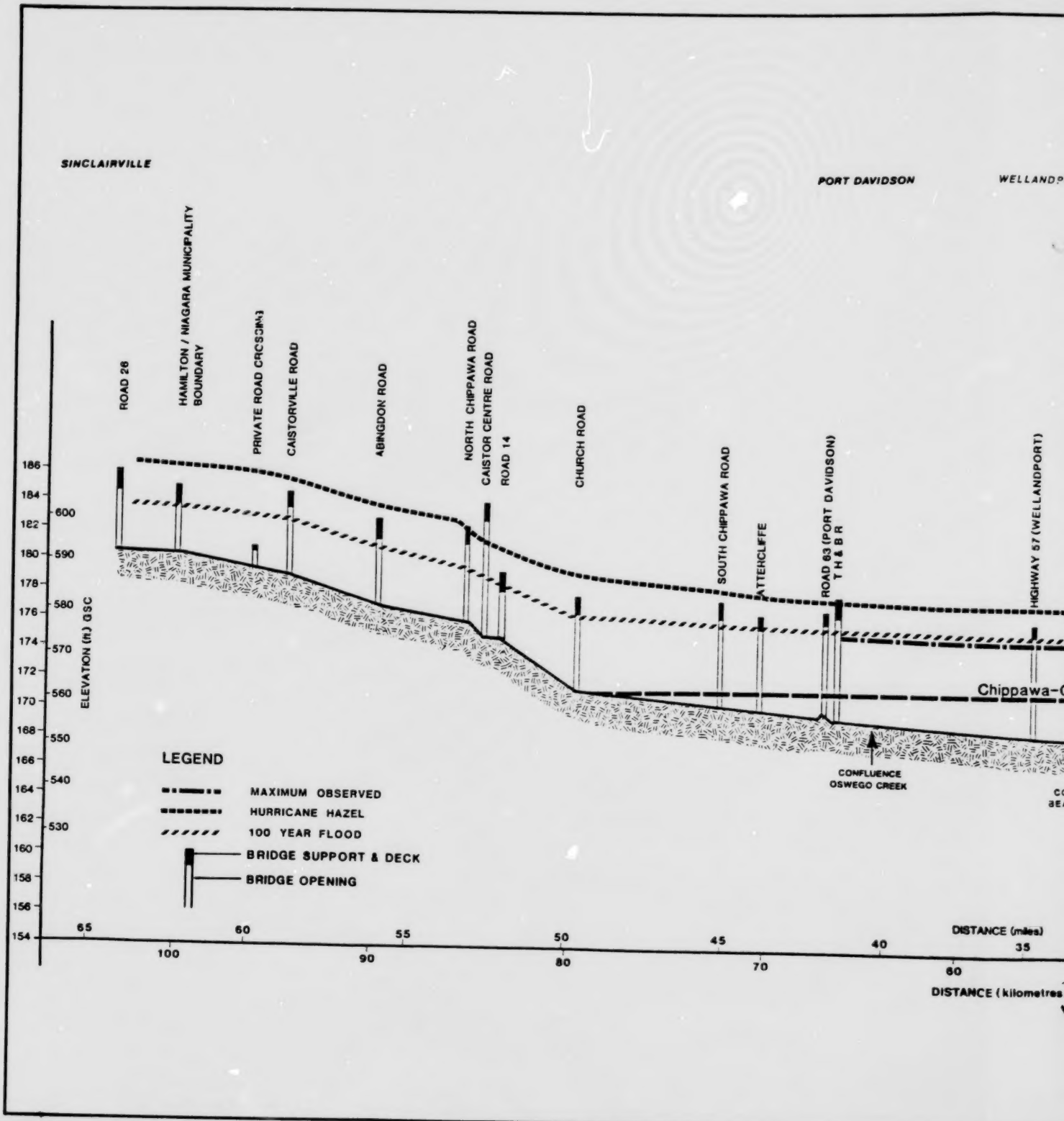
	5 Yr.	10 Yr.	25 Yr.	50 Yr.	100 Yr.	Regional
Brook's Bridge (Port Davidson)	70	80	95	105	115	515
Beckett's Bridge	125	145	170	190	205	540

3.2.4 WATER LEVELS

Water levels in the Niagara River and the Welland River are controlled by Ontario Hydro for power generation under an International Niagara Board of Control Directive (INBC, 1973). Ontario Hydro has reversed flow in a short section of the lower Welland River and supplies large volumes of water for power generation from the Niagara River (plus the small contribution from the Welland River) via the lower Welland River channel and the Chippawa Power Canal. A detailed description of Ontario Hydro Operations and the effects on the Welland River can be found in Appendix F.

Based on the current INBC Directive, the objective for water level in the Chippawa - Grass Island pool in the Niagara River is 171.2 m El. (see Figure 3.3). Under normal operations this level can fluctuate between 170.7 m El. and 171.7 m El., with the additional proviso that the maximum daily fluctuation cannot exceed 0.46 m (1.5 ft.). Under abnormal operating conditions, the level of the Niagara River at the original confluence with the Welland River is restricted to a minimum value of 170.6 m El. However, lower levels have been recorded infrequently (refer to Section 3.2.2.4).

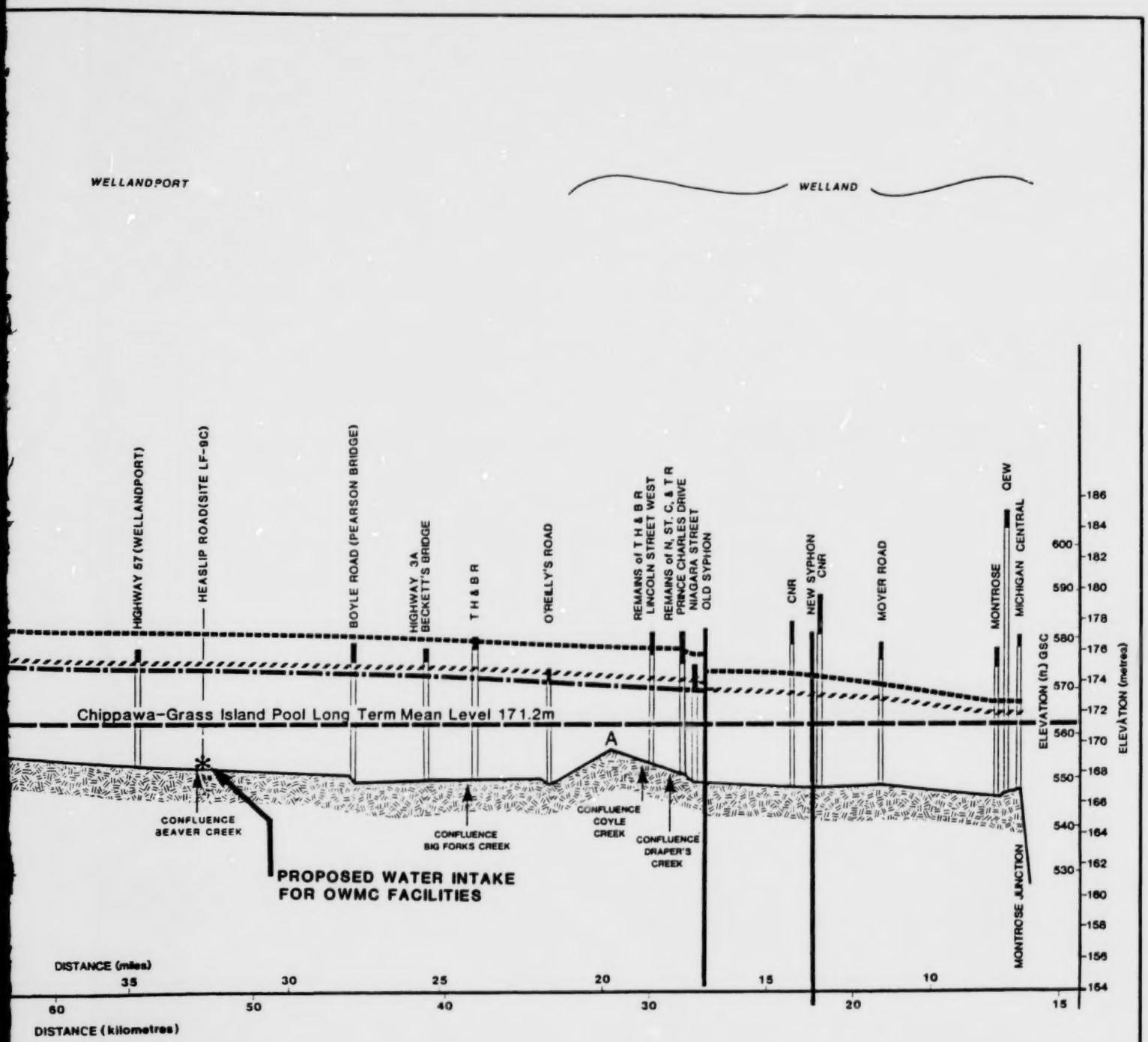
Given the normal head loss (0.24 m) from the Niagara River to the confluence with the Welland River and the Chippawa Power Canal at Montrose Junction, the lowest expected water level at Montrose Junction under normal operations is 170.5 m and under abnormal conditions is 170.4 m. Thus under "no flow" conditions in the Welland River, the minimum expected water level in the Welland River at Heaslip Road (proposed water intake location for OWMC facilities) is 170.4 m El.



OWMC Ontario Waste Management Corporation

DILLON

Source: Adapted from Welland River Study for Niagara Peninsula Conservation Authority (Dillon 1986)



WELLAND RIVER PROFILE

Figure 3.3

High water levels were also calculated in the Welland River Study (Dillon, 1985) from the Chippawa Power Canal upstream to Sinclairville for a complete range of design flood events. Computed levels of relevance to the Phase 4B Surface Water Study are summarized in Table 3.7.

TABLE 3.7

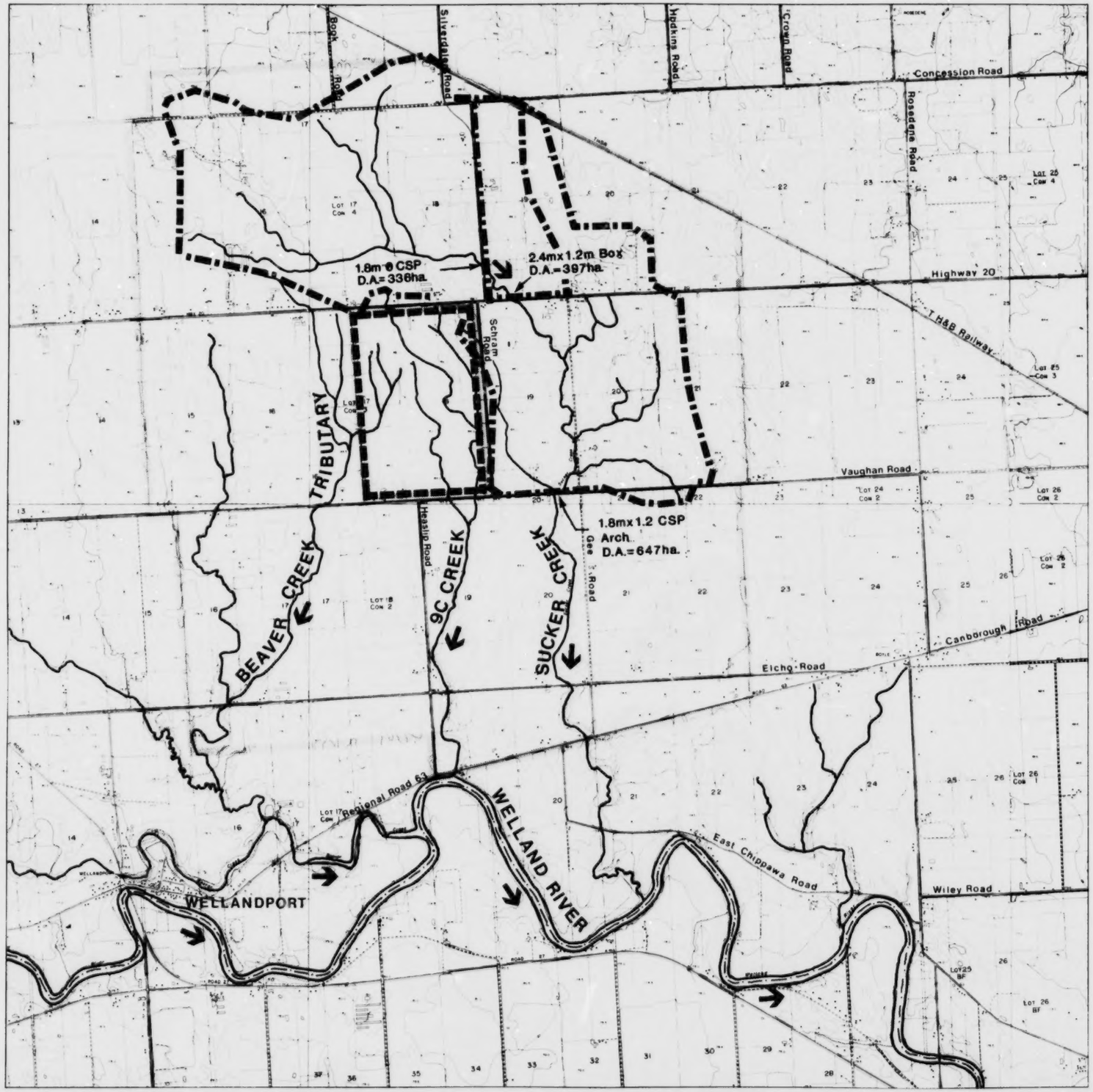
HIGH WATER LEVELS - WELLAND RIVER (m El.)

	5 Yr.	10 Yr.	25 Yr.	50 Yr.	100 Yr.	Hurricane Hazel
Highway 3A (Beckett's Bridge)	173.9	174.2	174.6	174.9	175.0	176.8
Boyle Road (Pearson Bridge)	174.1	174.4	174.8	175.0	175.3	177.1
Highway 57 (Wellandport)	174.2	174.5	174.9	175.1	175.4	177.3

High water levels recorded by the Niagara Peninsula Conservation Authority at Beckett's Bridge were 174.2 and 174.8 in 1984 and 1985 respectively.

Figure 3.3 shows a profile of computed Welland River levels for 1:100 year flood and for the Regional Flood (Hurricane Hazel). This figure also defines some maximum observed flood levels along the Welland River.

The Niagara Peninsula Conservation Authority currently uses the 1:100 year level as the Regulatory flood level. Accordingly, the Welland River flood plain in the site vicinity is defined by the Regulatory level of 175.3 m El. (see Figure 3.4).



OWMC Ontario Waste Management Corporation

Consultant: DILLON

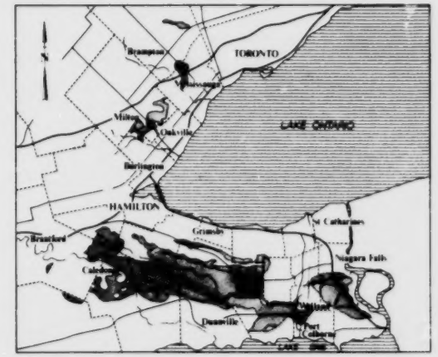
Legend:

- Sucker Creek Watershed Boundaries
- CSP – Corrugated Steel Pipe Culvert
- D.A. – Upstream Drainage Area
- Site Boundary
- Flow Direction
- Welland River Regulatory Floodline

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: OWMC PREFERRED SITE

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

SUCKER CREEK WATERSHED (TO VAUGHAN ROAD) AND WELLAND RIVER REGULATORY FLOODLINES

Figure 3.4

Throughout 1986, periodic measurements of the Welland River levels were taken at Wellandport (monitoring station 4A) and at the Pearson Bridge (monitoring station 4B). Water level measurements were generally taken coincident with water quality sampling episodes. The recorded levels at the two sites are summarized in Table 3.8. Estimated streamflows are based on the recorded mean daily flows at the WSC gauging station prorated to the confluence of Sucker Creek.

TABLE 3.8

1986 WATER LEVEL MEASUREMENTS - WELLAND RIVER

	STN. 4A, WELLAND RIVER, WELLANDPORT			STN. 4B, WELLAND RIVER, PEARSON BRIDGE		
Date	Staff Gauge (m)	Water Elev. (masl)	Discharge (m^3/s)	Staff Gauge (m)	Water Elev. (masl)	Discharge (m^3/s)
02 Apr. 1986	0.12	171.06	1.46	0.22	171.09	1.46
29 Apr. 1986	0.28	171.22	1.18	0.34	171.21	1.18
02 May 1986	0.315	171.26	0.34			
07 May 1986	0.245	171.19	0.19	0.31	171.18	0.19
31 July 1986	0.24	171.18	0.21	0.31	171.18	0.21
06 Aug. 1986	0.26	171.20	0.24			
07 Aug. 1986	0.34	171.28	0.37			
03 Sep. 1986	0.24	171.18	0.20	0.28	171.15	0.20
03 Oct. 1986	0.485	171.43	7.82	0.5	171.37	7.82
08 Oct. 1986	0.44	171.38	4.76			
11 Nov. 1986	0.205	171.15	3.06	0.275	171.15	3.06

Water levels readings at the two Welland River stations could not practically be taken coincidentally, particularly during water quality sampling episodes. Accordingly, higher downstream levels at Station 4B (e.g. on 2 April) do not necessarily imply a reversed gradient in the river.

3.2.5 WATER BALANCE - UPPER WELLAND RIVER WATERSHED

A simplified water balance calculation was carried out for the upper Welland watershed to define the major components of the hydrologic cycle and in particular the surface runoff and evapotranspiration components. Generally, the simplified water balance process is given by the following equation.

$P = E + R$ Where P = precipitation
E = evapotranspiration
R = runoff

Several Atmospheric Environment Service rainfall gauges in the vicinity of the Welland River watershed were identified. Those with a period of record exceeding 20 years were selected for analysis and are summarized below.

TABLE 3.9
SUMMARY OF PRECIPITATION GAUGING STATIONS FOR WATER BALANCE

Gauge	Average Annual Precipitation (mm)
Grimsby	876
Hamilton RBG	839
Niagara Falls	942
Vineland Station	818
Welland	938
Mean =	883

For calculation purposes, the high (942), low (818) and mean (883) values were used.

The Water Survey of Canada flow gauge on the Welland River below Caistor Corners was used in estimating average annual runoff (per unit area). This gauge records runoff from the upper 25% of the Welland River basin. Total annual discharge volumes for the period of record are summarized in Table 3.10.

TABLE 3.10
WELLAND RIVER BELOW CAISTOR CORNERS
ANNUAL DISCHARGE VOLUMES

Year	Discharge Volume (X 10^6 m^3)	Year	Discharge Volume (X 10^6 m^3)
1958	26.4	1972	110.0
1959	98.9	1973	96.3
1960	64.4	1974	87.5
1961	31.1	1975	63.2
1962	-	1976	97.4
1963	40.1	1977	104.0
1964	46.0	1978	74.6
1965	69.5	1979	84.3
1966	53.5	1980	51.4
1967	55.6	1981	77.6
1968	67.6	1982	103.0
1969	65.6	1983	87.6
1970	48.9	1984	115.0
1971	43.6	1985	107.0
		1986	89.8

The long-term mean annual discharge volume based on the data in Table 3.10 is 73.6 X 10^6 m^3. This converts to a unit area depth of 320 mm over the 230 km^2 drainage area at the flow gauge. This value compares very well with the 323 mm regional runoff value (Moin and Shaw, 1985).

Long-term evapotranspiration values are given in Table 3.11 below for various precipitation values described previously and the computed mean annual runoff value of 320 mm.

TABLE 3.11
EVAPOTRANSPIRATION ESTIMATES
(WATER BALANCE)

Mean Annual Precipitation (mm)	Mean Annual Runoff (mm)	Mean Annual Evapotranspiration (mm)
942	320	622
818	320	498
883	320	563

Results in Table 3.11 indicate that mean annual evapotranspiration may range from about 500 mm to 625 mm depending on the rainfall data selected.

A site specific annual water budget has also been developed for the Preferred Site by Gartner Lee (Gartner Lee Limited, 1987). In this case, evapotranspiration was estimated from temperature and precipitation data, in the absence of any local streamflow records. The results of their analysis are generally consistent with the water balance prepared for the upper Welland River watershed in this study.

3.3 SITE SURFACE DRAINAGE

3.3.1 GENERAL

The site is characterized by very little topographic relief (approximately 1.5 m from north to south) and is generally poorly drained. Drainage generally occurs in a north to south direction via very minor and ill-defined field swales. Some areas of the site are subject to local ponding during periods of snowmelt and wet weather.

The majority of the site area (70%) is drained by two swales which run the length of the site, outlet through culverts beneath Vaughan Road and join together immediately downstream from Vaughan Road. From this point, runoff is conveyed directly south to the Welland River. This swale and downstream watercourse has been designated as 9C Creek, for reference in this report.

The western portion of the site, which drains to several local tributaries of Beaver Creek, comprises approximately 26% of the total site drainage area. These tributaries join together just south of Vaughan Road (southwest from the site) and eventually drain to the Welland River just upstream from the 9C Creek outlet described above.

The remaining 4% of the drainage area (extreme northeast corner of the site) drains via roadside ditches and shallow field swales to Sucker Creek, to the north and east of the site.

With the aid of available topographic mapping (1:2000 scale, 0.5 m contour interval) and detailed site surveys, nine locations were identified where runoff presently leaves the site. Seven of these are culvert outlets beneath roads adjacent to the site

boundaries, while two are swales which cross the west site boundary. The outlets described above are shown on Figure 3.5 (in pocket at back of this volume).

In summary, under existing conditions, all site runoff drains to the Welland River via either the 9C Creek, Beaver Creek or Sucker Creek.

3.3.2 HYDROLOGIC MODELLING

The Preferred Site and several small external drainage areas, as shown on Figure 3.5, were divided into seven subwatersheds for flow calculation purposes. These subwatershed areas were developed to coincide with outlets where runoff crosses site boundaries. In general, the subwatersheds indicate the extent of the catchment area contributing runoff to each outlet.

A detailed discussion of the hydrologic analysis, including parameter selection, is provided in Appendix D.

3.3.3 RESULTS

Flow estimates at each storm water outlet from the site are summarized in Table 3.12. Culvert sizes and capacities, top of road elevations and 1:100 year water surface elevations at the culvert outlets are also presented for comparison.

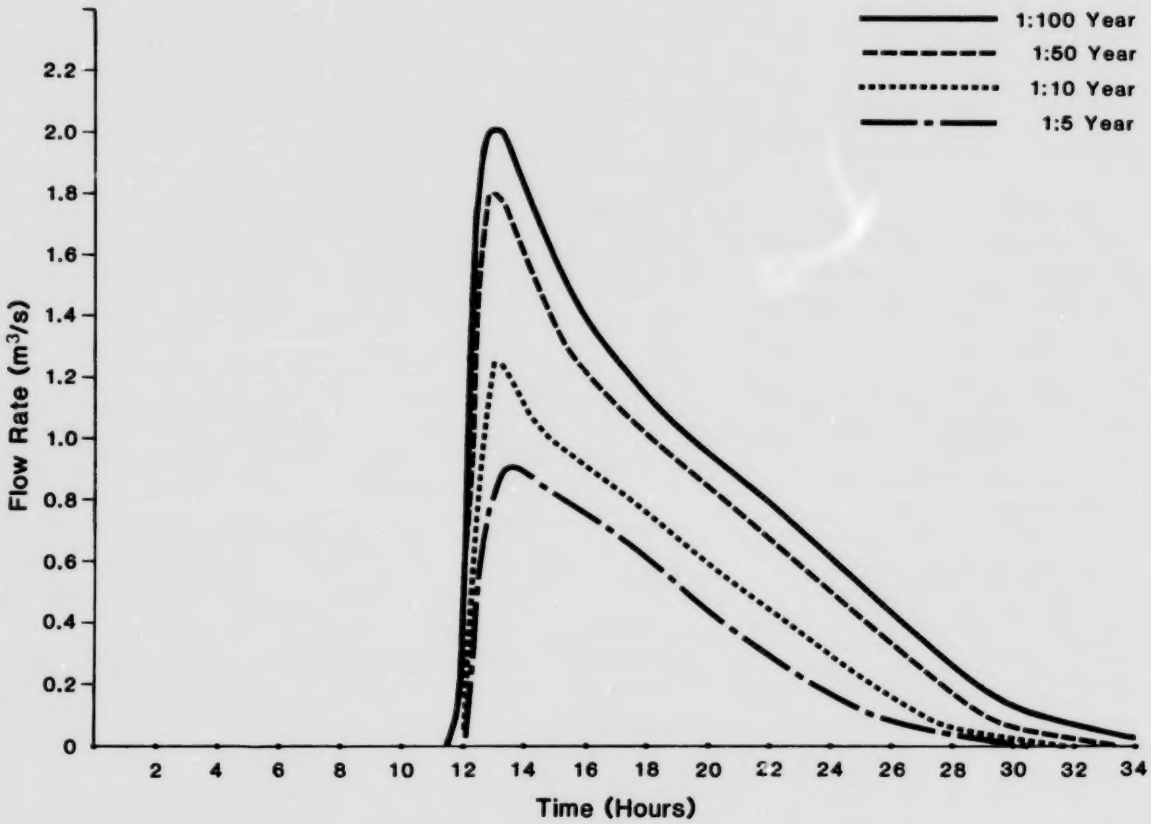
The estimated 1:100 year storm water surface elevation will be at or near the top of the road at each culvert outlet. The approximate area of flooding upstream from each of these culverts (1:100 year storm) is shown on Figure 3.5. The composite site hydrograph shown on Figure 3.6 indicates an existing condition 1:100 year peak flow leaving the site of 2.06 m^3/s, for all outlets combined.

TABLE 3.12

PREFERRED SITE

EXISTING CONDITIONS AT CULVERT OUTLETS

Outlet Reference (See Figure 3.5)	Drainage Area (ha)	Outlet Size (Ø CSP-m)	Flow Estimates (m^3/s) Q100	Q50	Q10	Q5	Capacity of Culvert at Top of Road (m^3/s)	Top of Road Elev. (m)	1:100 Year Water Surface (m)	Downstream Swale Slope %
1	17.1	-	0.95	0.80	0.57	0.34	-	-	-	0.1
2	4.6	-	0.52	0.44	0.26	0.19	-	-	-	0.5
3a 3b 3c	14.2	0.30 0.40 0.30	0.35	0.33	0.20	0.14	0.43	183.8	183.7	0.2
4	31.1	0.60	0.46	0.41	0.30	0.25	0.57	183.7	183.4	0.1
5	61.5	0.60	0.56	0.52	0.43	0.36	0.56	183.6	183.6	0.1
6	3.8	0.30	0.08	0.07	0.05	0.04	0.08	184.7	184.7	0.1
7	2.0	0.76	0.30	0.25	0.15	0.11	0.40	184.8	184.7	0.5



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COMPOSITE HYDROGRAPHS FROM SITE

Figure 3.6

While the actual site area is 124 ha, the composite hydrograph includes runoff from some small external areas (refer to Figure 3.5), bringing the total area modelled to slightly more than 134 ha.

The estimated flows and flood levels account for the limited capacity of the existing culverts and the considerable storage available behind these structures.

3.4 SURFACE DRAINAGE - SITE VICINITY

3.4.1 SUCKER CREEK - FLOOD POTENTIAL

As shown on Figure 3.4, Sucker Creek drains lands to the north and east of the site. It is the only off-site watercourse of significance in the vicinity of the site which could potentially cause site flooding under extreme conditions. To assess the potential for Sucker Creek to flood the site, a hydrologic/hydraulic analysis was carried out.

The OTTHYMO model was used to estimate peak flows, while culvert and weir hydraulics were used to estimate water surface elevations upstream from Silverdale Road, Highway 20 and Vaughan Road. Details associated with input data and modelling methodology are presented in Appendix E.

Flow estimates and water surface elevation estimates are summarized in Table 3.13. The areas encompassed by the Regional Storm flood elevations immediately upstream from each road crossing are shaded on Figure 3.5. The 1:100 year flood elevations would encompass only slightly less area and are not shown.

TABLE 3.13
SUMMARY OF FLOW AND WATER SURFACE ELEVATION ESTIMATES - SUCKER CREEK

	REGIONAL STORM		1:100 YEAR STORM	
	Q_p (m^3/s)	W.S. El. (m)	Q_p (m^3/s)	W.S. El. (m)
Silverdale Road	26.3	184.9	9.6	184.7
Highway 20	28.5	184.5	9.8	184.2
Vaughan Road	39.1	181.5	12.1	181.3

Notes: i) Qp = peak flow estimate
ii) W.S. El. = Water Surface Elevation

The results indicates that Regional Storm flood levels resulting from limited capacity culverts at Silverdale Road, Highway 20 and Vaughan Road will have little or no impact on the Preferred Site. Backflow through the two culverts beneath Highway 20, upstream from Silverdale Road, may occur but will not have significant impact on flows through the site under existing conditions. Also this will be easily mitigated at the time of site development with proposed ditching and berming around the perimeter of the site.

3.4.2 FLOW AND WATER LEVEL MONITORING - 1986

The staff gauges installed at selected locations in the vicinity of the site were read on an intermittent basis during 1986. These staff gauges were located as follows:

Station 1A - Unnamed tributary of Beaver Creek on Elcho Road

Station 2A - 9C Creek at Elcho Road

Station 3A - Sucker Creek at Vaughan Road.

These locations are shown on Figure 2.1.

The streamflow at Stations 1A, 2A and 3A was gauged on several occasions during the year. The gauging times were chosen to provide of a range of flow conditions, i.e. high, moderate and low flow conditions. During 1986, the high flow measurements were made during the melt periods in January and March. A low flow measurement was taken in early May when the flows were near zero. Other no flow observations were made periodically during the summer. Additional gauging was conducted in the fall to measure the low to moderate flows. In addition, the water levels at Station 3A were measured on a more frequent, but irregular, basis throughout the year. The accumulated streamflow gauging and water level data are shown on Table 3.14.

In addition to the stations listed above, the following stations were also gauged and/or had water levels measured on an occasional basis during the year.

Station 2B - Western Ditch, on site at Vaughan Road
Station 2C - Eastern Ditch, on site at Vaughan Road
Station 3B - Sucker Creek at Elcho Road, and
Station 3C - Sucker Creek at Canborough Road.

tream Flow and Water Level Measurements
– Local Creeks
Table 3.14

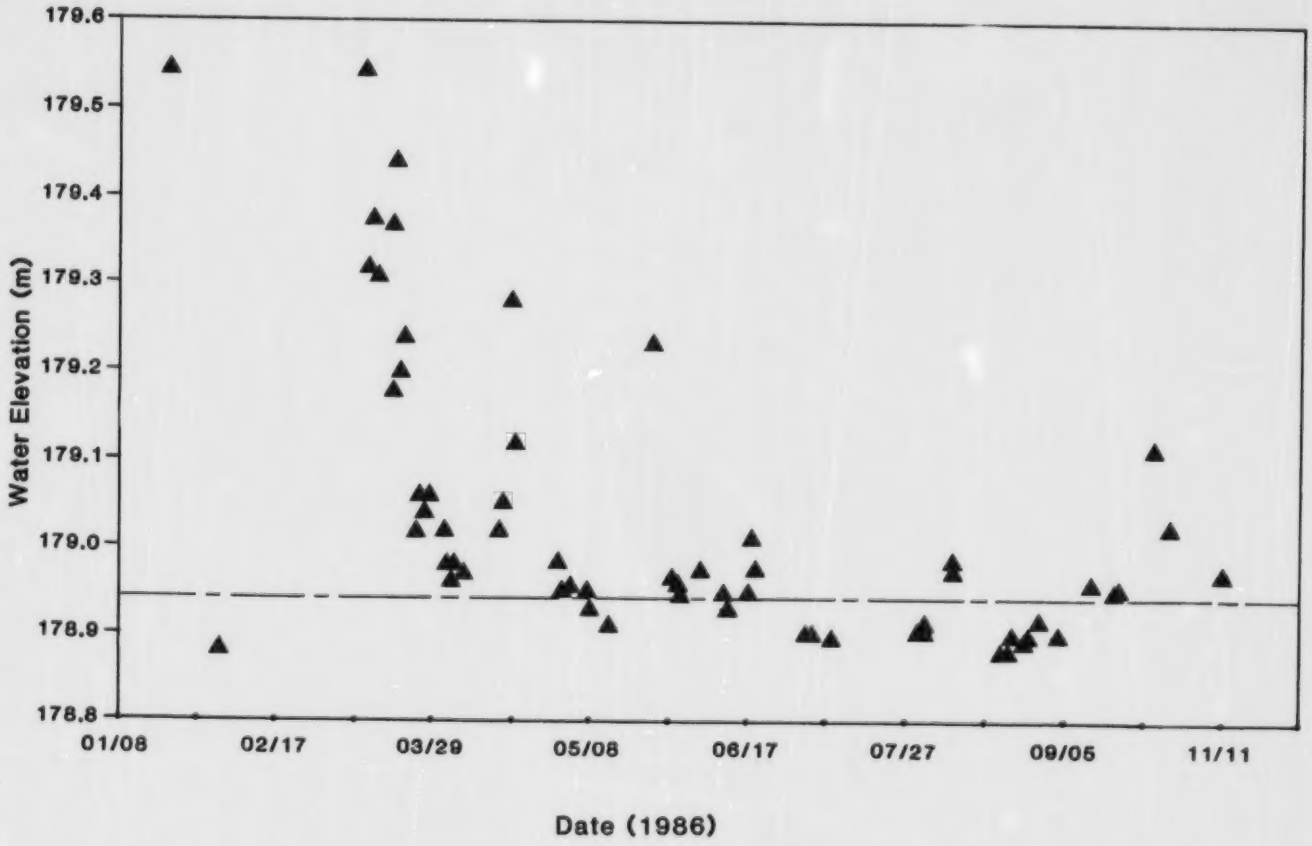
DATE	STATION 1A, ELCHO ROAD					STATION 2A, 9C CREEK AT ELCHO ROAD					STATION 3A, SUCKER CREEK ON VAUGHAN ROAD				
	WAT LEV SOFFIT (D/S)	WAT LEV STAFF G. (m)	ELEV. WATER (masl)	DISCHARGE (L/s)	GAUGED/ ESTIMATED	WAT LEV SOFFIT (D/S)	WAT LEV STAFF G. (m)	ELEV. WATER (masl)	DISCHARGE (L/s)	GAUGED/ ESTIMATED	WAT LEV SOFFIT (D/S)	WAT LEV STAFF G. (m)	ELEV. WATER (masl)	DISCHARGE (L/s)	GAUGED/ ESTIMATED
20-Jan-86	0.889	1.00	175.01	926	G	0.089	0.564	176.32	400	G	0.305	0.903	179.54	1597	G
02-Feb-86												0.24	178.88	0	E
11-Mar-86	0.96	0.93	174.94	700	E	0	0.653	176.41	>> 400	E	0.305	0.903	179.54	1619	G
12-Mar-86	1.15	0.74	174.75	820	E	0.15	0.503	176.26	75	E	0.53	0.678	179.32	618	G
13-Mar-86											0.475	0.733	179.37	745	E
14-Mar-86											0.54	0.668	179.31	540	E
18-Mar-86											0.48	0.728	179.37	745	E
18-Mar-86											0.67	0.538	179.18	195	E
19-Mar-86											0.41	0.798	179.44	1050	E
20-Mar-86											0.65	0.558	179.20	255	E
21-Mar-86											0.61	0.598	179.24	355	E
24-Mar-86											0.83	0.378	179.02	23	E
25-Mar-86											0.79	0.418	179.06	40	E
26-Mar-86											0.81	0.398	179.04	30	E
27-Mar-86											0.79	0.418	179.06	40	E
31-Mar-86											0.83	0.378	179.02	23	E
01-Apr-86											0.87	0.338	178.98	15	E
02-Apr-86												0.32	178.96	5	E
03-Apr-86											0.87	0.338	178.98	15	E
05-Apr-86											0.88	0.328	178.97	10	E
14-Apr-86											0.83	0.378	179.02	23	E
15-Apr-86											0.8	0.408	179.05	35	E
17-Apr-86											0.57	0.638	179.28	445	E
18-Apr-86											0.73	0.478	179.12	50	E
29-Apr-86							0.27	176.03	5	E		0.34	178.98	15	E
30-Apr-86											0.9	0.308	178.95	0.5	E
02-May-86	1.61	0.28	174.29	0.09	G	0.39	0.263	176.02	< 0.1	E	0.895	0.313	178.95	0.5	G
06-May-86											0.9	0.308	178.95	0.5	E
07-May-86	1.67	0.25	174.26	0	E						0.92	0.288	178.93	0	E
12-May-86												0.27	178.91	0	E
23-May-86												0.59	179.23	330	E
28-May-86												0.322	178.96	5	E
29-May-86												0.315	178.96	0.5	E
30-May-86												0.304	178.94	0	E
04-Jun-86		0.30	174.31	5	E		0.288	176.05	6	E		0.332	178.97	10	E
10-Jun-86												0.305	178.95	0.5	E
11-Jun-86												0.288	178.93	0	E
16-Jun-86												0.305	178.95	0.5	E
17-Jun-86												0.368	179.01	20	E
18-Jun-86												0.334	178.97	10	E
01-Jul-86												0.26	178.90	0	E
02-Jul-86												0.26	178.90	0	E
07-Jul-86												0.254	178.89	0	E
29-Jul-86												0.263	178.90	0	E
30-Jul-86												0.263	178.90	0	E
31-Jul-86												0.263	178.90	0	E
31-Jul-86		0.22	174.23	0	E		0.22	175.98	0	E		0.27	178.91	0	E
07-Aug-86							0.34	176.10	10	E		0.33	178.97	10	E
07-Aug-86												0.34	178.98	15	E
20-Aug-86												0.241	178.88	0	E
21-Aug-86												0.24	178.88	0	E
22-Aug-86												0.256	178.90	0	E
25-Aug-86												0.251	178.89	0	E
26-Aug-86												0.256	178.90	0	E
29-Aug-86												0.274	178.91	0	E
02-Sep-86		0.23	174.24	0	E										
03-Sep-86		0.22	174.23	0	E		0.12	175.88	0	E		0.26	178.90	0	E
11-Sep-86												0.316	178.96	5	E
17-Sep-86												0.305	178.95	0.5	E
18-Sep-86												0.308	178.95	0.5	E
03-Oct-86		0.55	174.56	54	G		0.49	176.25	49	G		0.49	179.13	89	G
08-Oct-86												0.40	179.04	30	E
11-Nov-86		0.37	174.38	10	E		0.375	176.14	15	E		0.345	178.99	15	E

Stations 2B and 2C could best be described as shallow swales that convey runoff from the site. Runoff was observed within these swales during the spring melt period but they were dry through much of the summer period. In a typical summer, these ditches would only flow during thunderstorms and other significant rainfall events. Stations 3B and 3C are located on Sucker Creek downstream from the site.

On each gauging occasion the discharge was recorded for the gauged station. The water level was translated to a water elevation when the geodetic datum of the staff gauge was calculated. Table 3.14 shows that a large number of water level readings were taken at the primary Station 3A, on Sucker Creek. Sucker Creek is the most significant stream that flows in the immediate vicinity of the site. Figure 3.7 shows the recorded water levels at this station during 1986.

The water levels and matched streamflow gaugings from the Stations 1A, 2A and 3A were plotted as rating curves for each station. A rating curve relates the streamflow to a reference water elevation. In these cases the reference water level is the elevation of the water in the pool just downstream from the culvert where the gauging was taken. The rating curve for Station 3A is shown in Figure 3.8.

The streams in the vicinity of the site are intermittent as they flow periodically during the fall, winter and spring, but are normally dry during the water deficit months of the summer. Table 3.14 and Figure 3.7 show that the water levels at this station fall below the elevation of a zero flow condition. At this stage the stream looks like a series of disconnected stagnant pools. During 1986, Sucker Creek exhibited some streamflow much of the time as a result of above average precipitation.



NOTE: Elevation, below which no flow occurs = 178.94m.

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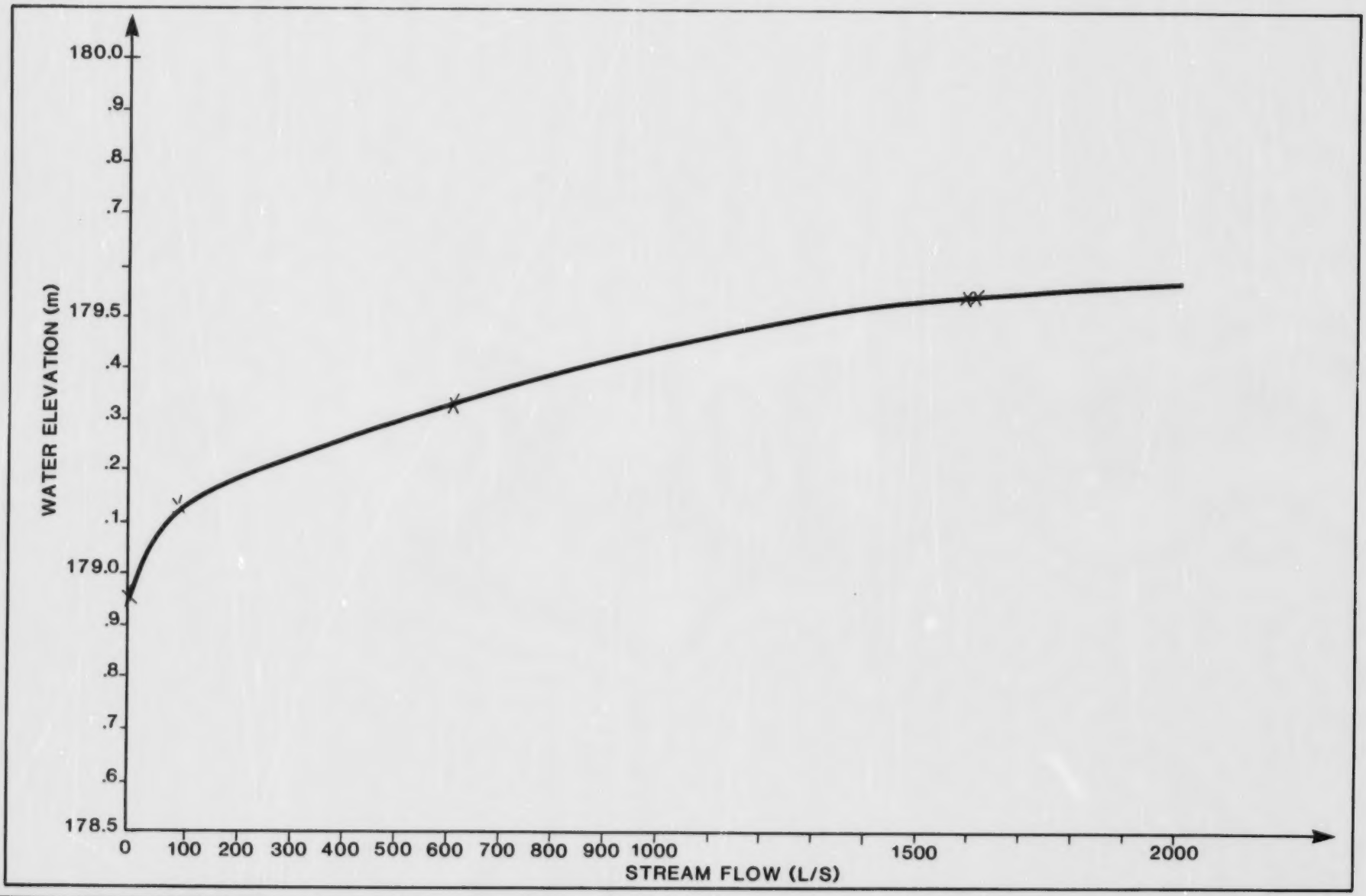
WATER LEVELS AT STATION 3A

Figure 3.7



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PROVISIONAL RATING CURVE
STATION 3A

Figure 3.8

All the streams respond to storm events but during the summer they flow for short periods of time before reverting to the no-flow condition.

3.4.3 COMPARISON WITH RESULTS FROM PHASE 4A STUDIES

The improved detail available in the Phase 4B study verified the qualitative statements made in the Phase 4A report that the site is characterized by little topographic relief, is poorly drained and is subject to local ponding during wet weather.

Quantitatively, drainage areas were revised on the basis of the new detailed mapping, two additional culvert outlets have been identified and OTTHYMO generated flows are significantly lower than flows initially estimated by the Rational Method. However, it is likely, with improved detail at the other sites, that OTTHYMO generated flows would be lower than the initial Rational Method flow estimates.

Phase 4A analyses concluded that "...it does not appear that the Sucker Creek floodplain could encroach upon the site during the Regional Storm...". Hydrologic/hydraulic analyses in Phase 4B have concluded some backflow through the two Highway 20 culverts may occur onto the site due to surcharge at the Sucker Creek - Silverdale Road crossing. However, the effect of this potential backflow on site flooding is considered minor, and can be mitigated at the detailed design stage of the facility.

Thus, although some variations from the Phase 4A results have been identified, these variations are considered minor in terms of effect on the site selection process.

3.5 SURFACE WATER USE

3.5.1 PURPOSE AND SCOPE

The uses of surface water resources for domestic, livestock and general agricultural purposes in the vicinity of the Preferred Site are characterized in this section.

This area is not serviced by a regional or municipal treated water supply system. Most residences and farming operations rely on individual water supply systems which may use ground water, rain water (cisterns), pond water, creek water, bottled or purchased water, or any combination of these, as a source of supply. Although this study focuses on surface water as a source of supply, cisterns are briefly described in order to place surface water usage in the context of total water usage in the Preferred Site area.

3.5.2 BACKGROUND

Water use in the vicinity of the Preferred Site was determined as part of the Phase 4A studies and is documented in the "Technical Appendix" (GLAL, 1985). The Phase 4A study utilized water use information obtained during a house-to-house survey which included residents and landowners on the site and on adjacent properties. A total of 17 residents provided water use information at that time. The information is summarized in Table 6 of the "Technical Appendix" LF-9C (GLAL, 1985) and copies of the actual interview forms are on file with the Ontario Waste Management Corporation.

The Phase 4B water use investigation builds on the results of the Phase 4A study.

3.5.3 APPROACH

The use of surface water in the vicinity of the proposed site is characterized from the results of a house-to-house water use survey of landowners and tenants. The survey was conducted as part of a larger survey of water use, including the use of both surface water and ground water resources.

The survey was conducted by Gartner Lee Limited as a cooperative joint effort. The survey was done jointly owing to the combined interest in the use of water resources around the site, and to avoid duplication of effort in interviewing and in questionnaire preparation. The field data were collected by the same person who visited all properties within the study area. This insured a uniformity in the information obtained during the interviews.

The house-to-house survey of water use was completed in late August and early September, 1986. Information collected at this time included:

- name, ownership or tenant status, interview and assessment role numbers, location;
- water use information including source, quantity and quality of supply;
- characteristics of on-site surface water and surface water use;
- wells and cistern construction details;
- storage tanks, treatment and problems with supply; and
- location of oil and gas wells.

The survey addressed such items as the source of the residents' potable and non-potable water, reliance on cisterns or ponds and the use of surface water for livestock watering. Non-potable water is likely of poorer quality, with uses restricted to washing and cleaning, but is not used for drinking or cooking. The respondents were asked about flooding on their properties and soil erosion problems. The parts of the survey that pertain directly to the use of surface water were extracted from the interview forms for use in this evaluation. A sample interview form is contained in Appendix B.

On each property repeated attempts were made to conduct the interviews with the tenants and/or landowners. In a few cases, the interviews were declined. Interviews with some long-time residents provided historical insight about other properties in the study area. At some locations, the information gained from the interviews was supplemented with additional information from other sources. An example of this additional information is the number and locations of ponds taken from recent aerial photographs.

No water samples for chemical analyses were collected during the survey. However, as part of the survey, the residents were asked whether a sample could be collected in the future. Over 60% (36 respondents) of those surveyed indicated a willingness to have their water sampled.

3.5.4 STUDY AREA

The study area is shown on Figure 3.9. It includes the properties on the site and adjacent to the site. The properties surrounding Sucker Creek are included together with the properties that lie downstream from the site, i.e. between the site and the Welland River.

It should be noted that the study area selected for the study of surface water resources is similar to but somewhat smaller than the equivalent study area selected by the hydrogeologic consultant (GLL, 1987). The surface water study area was selected to include the catchments that drain the proposed site (9C Creek and Sucker Creek). It extends from the midpoint of the concession north (upstream) of the site, down to the Welland River. The study area being reported herein does not include the Welland River downstream from the site.

3.5.5 WATER USE

The water use in the vicinity of the proposed site can be most easily characterized in terms of the source of the water and its disposition. The results of the survey are given in Table 3.15. The survey includes a total of 56 interviews of property owners/ tenants representing approximately 149 residents.

Generally, most of the houses in the study area use cisterns as the main source of both potable and non-potable water. The study area and the locations of these houses are shown in Figure 3.9. Thirty-six households indicated the use of cisterns for their domestic water supplies, with three locations having two cisterns. Twenty-one households indicated that their cistern was used for potable water supplies. The interviews indicated that cisterns supply potable water to a total of 93 people. A further four households indicated that their cisterns were used to supply only non-potable water. Seventeen people live in these four households. One cistern was recorded as not being used and another is used only to wash cars.

A number of the interviews reported that their cisterns were fed by ground water. Reference should be made to the hydrogeological consultant's report (GLL, 1987) for the description of the use of cistern water within the context of local ground water use.

Surface Water Use in the Vicinity of the OWMC Preferred Site
Table 3.15

NAME	ASSESSMENT ROLL #	INTERVIEW	CISTERN	USE	# PEOPLE	PONDS	USE	# USERS	FLOODING	ACCESS	RIVER EROSION
H OTTEN	10-011	86.30	NO USE RECORDED								
H DIEK	10-076	86.43	YES	P+NP	6	NO USE RECORDED			YES, ROAD	YES	
G MATHESON	10-077	INTERVIEW DECLINED									
S KSZAN	10-080	86.45	INTERVIEW DECLINED								
Y FLAMELING	10-081	86.46	YES	P+NP	3	YES	OCCAS CATTLE		YES,LOCAL		
S KSZAN	10-082	86.45	YES	P+NP	4						
C BEAMER	10-100	86.21	YES	NP	5	YES	OCCASIONAL STOCK		YES,ROAD	YES	
K BEAMER	10-101	86.20	YES	NP	5	NO USE RECORDED			YES,ROAD	YES	
W ZDICNAVSKY	10-103	86.19	YES	NP	2	NO USE RECORDED					
J MELON	10-105	86.18	YES	P+NP	2	YES	CATTLE	42	YES,ROAD		
B MCPHERSON	10-106	86.16	YES	NONE		YES	NO USE RECORDED				
W DEVRIES	10-108	86.13	YES	P+NP	2	NO USE RECORDED					
C BEAMER	10-155	86.21	NO USE RECORDED								
G STROOP	10-156	86.28	YES	P+NP	4	NO USE RECORDED					
W VANDERHEIDE	10-158	86.29	YES	P+NP,NONE						YES	
C TSIANTOULUS	10-160	86.17	YES	P+NP	5	YES	TURKEYS	15000		YES	
R ALLAN / CHOW	10-161	86.94	NO USE RECORDED			YES	SPRAY		YES		
C HUIZINGA	10-162	86.1	YES	P+NP	4	YES	CATTLE,GE	90,12	SEASONAL		
DELUCA / FODEN	5-122	86.23	NO USE RECORDED			YES	NO USE RECORDED				
G VANDERVELDE	5-123	86.24	NO USE RECORDED			YES	NO USE RECORDED				
K GRIEPSMA	5-124	86.26	YES	P+NP	3	YES, NO CURRENT USE					
S CHEEL	5-125	86.27	YES	P+NP, NP	1	YES	NO USE RECORDED				
CECIL GRACEY	6-111	86.58	YES	P+NP	4	NO USE RECORDED					
J DINIZ	6-114	86.41	YES			INTERVIEW DECLINED					
A OTTEN	6-149	86.77	NO USE RECORDED								
G BOVERHOF	6-198	86.57	YES	P+NP	8	YES	OCCAS STO	100			
V VALLEY	6-198	86.57	YES	P+NP	3	NO USE RECORDED					
SZWEC	6-227	86.85	YES	P+NP	1	NO USE RECORDED					
J TRUDELL	6-255	86.84	YES	NO USE RECORDED		YES	NO USE RECORDED				
D HORTON	6-270	86.40	YES	P+NP	4	NO USE RECORDED					
A BORODYN	6-302	86.22	YES	P+NP	6	B/U FOR TURKEYS					
A OTTEN	7-002	86.77	NO USE RECORDED								
COLLACUT	7-003.5	86.67	YES	P+NP+CA	2 + 3 CATTLE,		NO PONDS				
E GRACEY	7-014	86.52	YES	P+NP	5	YES	OCCASIONAL CATTLE		YES	YES	
D SCHUENDER	7-015	86.51	YES	CAR WASH		YES	SPRAYING		YES	YES	YES
D SCHUENDER	7-016	86.51	NO USE RECORDED						YES		YES
R DOBRUCKI	7-020	86.88	YES	NO USE RECORDED, FORMERLY P+NP							YES
A AUGUSTYN	7-021	86.50	YES	P+NP	2	YES	NO USE RECORDED				
A AUGUSTYN	7-022	86.50	YES	NOT USED		YES	NO USE RECORDED				
W HEASLIP	7-09[illegible]	86.56	NO USE RECORDED			FROM 7.143	P+NP B/U	2			
W HEASLIP	7-093	86.56	NO USE RECORDED			YES	FORMERLY CATTLE			OCCASIONAL	
BRIAN HEASLIP	7-093.1	86.64	NO USE RECORDED			FROM 7.143	P+NP	5		OCCASIONAL	
R M NIAGARA	7-093.2	86.96	VACANT LAND, NO INTERVIEW								
M HILL	7-093.3	86.65	NO USE RECORDED			FROM 7.94	NP	2			
G HILL	7-094	86.66	YES	ABANDONED		YES	NO USE RECORDED		INTERVIEW DECLINED		
W HEASLIP	7-143	86.56	ALSO SEE INTERVIEW 86.63			FROM 7.143	P+NP B/U			YES	
H COOK	7-143	86.63	YES	P+NP	4	FROM 7.143	P+NP B/U	4			
BRIAN HEASLIP	7-143	86.64	NO USE RECORDED			YES	CATTLE	80			
J CRITCHLEY	7-144	86.62	YES	NP	5	FROM 7.143	P+NP B/U	5			
W HEASLIP	7-145	86.56	NO USE RECORDED			YES	NO USE RECORDED				
L SNIPPE	7-148	86.68	NO USE RECORDED								
BARRY HEASLIP	7-240	86.54	NO USE RECORDED			FROM 7.143	P+NP	4			
V VITUCCI	7-240.5	86.53	NO USE RECORDED			FROM 7.143	P+NP	5			
W HEASLIP	7-240.5	86.55	NO USE RECORDED			FROM 7.143	P+NP B/U				
L SNIPPE	7-264	86.42	YES	P+NP	3	NO USE RECORDED				YES	
Y FLAMELING	7-268	86.46	NO USE RECORDED			YES	NO USE RECORDED				
CECIL GRACEY	7-269	86.58	NO USE RECORDED								
J VAN WYNGAARTEN	7-270	86.93	NO USE RECORDED			YES	NO USE RECORDED				

The cisterns are also filled by rainwater during most of the year. However, several interviews recorded the need to "make up" the domestic water supply with water purchased externally and transported in by truck.

Several interviews reported the existence of ponds. The locations of these ponds are shown in Figure 3.9. The pond data collected in the interview process has been supplemented by a review of 1:10 000 scale aerial photography of the study area. Some of the ponds appear to be the result of imperfect surface drainage and could better be classified as "sloughs". These ponds appear seasonally.

There are approximately 32 ponds within the surface water use study area. The bulk of the ponds are used for stock water or for no particular use. The use of ponds for agriculture ranges from occasional use by cattle to being a water supply for 15 000 turkeys. Approximately 200 cattle are watered from ponds within the study area. At two farms the ponds are used only to supply water for spraying of herbicides and/or pesticides. The locations of these uses are shown in Figure 3.9.

Some farmers reported that their livestock drink from the local streams and creeks. Most creeks and drainage ditches within the study area flow intermittently and are only infrequently available as a source of water. Farmers located on the banks of the Welland River and 9C Creek record that animals have occasional access to these streams. On several occasions cattle were observed to browse and drink in the vicinity of unfenced streams throughout the study area. The use of surface water for livestock watering is seasonal.

None of the creeks or streams were reported to be used as a source of domestic drinking water.

Four properties near the southern end of the study area draw their domestic water supplies from a large pond on the property of Mr. William Heaslip. This pond is located south of, and adjacent to Elcho Road, just west of Sucker Creek. The pond water is used for both potable and non-potable uses, or as a back-up supply to a domestic well. A total of nine people use this pond as their main supply of domestic water. A second pond on the southwest corner of the same property near the Canborough Road also supplies domestic water to one family of four people.

A third pond located on Canborough Road, just west of Heaslip Road was reported to have been used for drinking water and non-potable water use by two residences, although use of the pond for drinking water was discontinued a few years ago due to poor water quality.

The water quality from ponds used for drinking is reported to be good. Water from these ponds is filtered through a gravel bed into a wet well from which it is pumped to the residences. Periodic chlorination of the ponds is the only reported form of chemical treatment.

Several interviews indicated no use of surface water. A review of these interviews shows that the majority of these properties draw their main water supplies from ground water sources. For completeness, the reader is referred to the Gartner Lee Limited Report (GLL, 1987).

No households are known to directly draw domestic water from streams in the study area, including the Welland River.

Places where flooding was recorded as a problem are also shown on Figure 3.9. Flooding in stream channels was only recorded as a problem along Sucker Creek in the northern end of

the study area, and on the upper reaches of 9C Creek. Several interviews recorded seasonal flooding problems on roadways. Localized erosion was reported along 9C Creek.

3.6 WATER QUALITY

3.6.1 WATER QUALITY QA/QC DATA

As discussed in Section 2.3.2.5, quality assurance checks on analytical data can be used to assess the reliability of all analyses carried out.

In the 1986 Phase 4B Background Water Quality Assessment duplicate sets of water and sediment samples collected from the Welland River at Pearson Bridge were analyzed by two laboratories for all of the parameters of interest. The duplicate water samples were analyzed on three occasions:

2 April 1986
3 September 1986
11 November 1986

The differences in analytical results from the two laboratories were assessed to confirm that the results obtained from the study's primary laboratories were reliable, and thus that the water quality information obtained in this study is representative of actual water quality in the river and creeks. Similarly, duplicate sediment samples were analyzed to determine the reliability of sediment analysis. 'Field' blank samples of laboratory distilled water were evaluated to confirm that no bottle or airborne contaminants were impacting water quality results. A detailed assessment of the 1986 QA/QC results is shown in Appendix L. A brief summary of the results follows.

3.6.2 QA/QC RESULTS

The results of the comparison of duplicate analyses conducted by the two laboratories was extremely favourable. The difference in analytical results for 175 of the 178 water quality parameters tested were minimal on all three occasions, see Tables L1, L2, L3. This indicates that the analyses conducted by the study's primary laboratories, Barringer Magenta and Mann Testing, are reliable. Similarly sediment and 'field' blank QA/QC checks were satisfactory.

The duplicate analytical results for three water quality parameters:

- phenolics
- biochemical oxygen demand (BOD)
- bacteria

were found to be quite different (one order of magnitude). The possible reasons for the differences in results were investigated and corrective action was taken early in the study to minimize the differences in QA/QC results and ensure the quality of all of the study results. To date there is a tenfold difference between the phenolics results obtained by the primary and QA/QC laboratories. The reasons for the difference cannot be explained. Evidence leads the study team to believe that the results of the primary laboratory are the more realistic, and thus that the 1986 phenolics data for the entire study are reliable.

In conclusion, the QA/QC assessment of the 1986 water and sediment quality indicates that the results obtained from the primary laboratories to the study are reliable. Thus, the water and sediment quality data discussed in the following sections is considered to be a good estimate of actual quality on the days of survey.

3.6.3 WATER QUALITY - HISTORICAL SUMMARY (WELLAND RIVER)

The Welland River has been analyzed monthly over a period of several years by the Ministry of the Environment (MOE, 1987b). General chemistry, nutrient, trace constituents and bacteriological data are available including many of the parameters included in the present study. Limited data on pesticides and some chlorinated organics is available for one site. No historical data is available for small tributaries such as Sucker Creek and 9C Creek.

A discussion of the historical data is provided below. It is organized into sections entitled General Chemistry, Nutrients, Bacteriological, Trace Constituents and Priority Organics. Mean and peak values, of parameters measured, and their relationship to the criteria, are summarized in Table 3.16 and in Sub-sections 3.6.3.1 to 3.6.3.5. This summary is derived from the two MOE water quality sampling stations on the Welland River nearest the site. These are located at Sinclairville and at a location south of the Welland Airport (for general locations refer to Figure 1.4). The complete data printout for these MOE stations is reproduced, as received in Appendix J.

An overview of the historical data suggests that the data from the Welland Airport station is more comparable to the data obtained for this report than the historical data from the Sinclairville station. This observation is based on a visual inspection of the data for major water quality indicators, total residue, alkalinity, hardness and some specific ions, chloride and sulphate. In its upper reaches, the Welland River is harder, more alkaline, higher in total solids. The major anions, chloride and sulphate are also higher. It is also apparent that changes in water quality parameter values are more influenced by the flow in the Welland River in the upper reaches. High values are generally associated with periods of low precipitation; some parameters such

TABLE 3.16

HISTORICAL DATA SUMMARY: MOE MEASUREMENTS AT THE BRIDGES AT SINCLAIRVILLE AND SOUTH OF WELLAND AIRPORT, 1978-86

GENERAL CHEMISTRY

Parameters	Temperature (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (umho/cm) Ambient	Conductivity (umho/cm) 25°C
Upstream (Sinclairville Bridge)					
Maximum Value	26.5	8.3	13.6	1000	1580
Mean Value	10.7	7.7	8.6	496	669
Minimum Value	0.5	6.5	4.0	155	195
Downstream (Bridge S. of Welland Airport)					
Maximum Value	27.0	8.25	13.2	550	807
Mean Value	12.1	7.7	8.1	335	438
Minimum Value	0.2	6.40	1.8	145	138

Parameters	Total Residue (mg/L)	Turbidity (FTU)	Alkalinity (mg/L)	Total Dissolved Organic Carbon (mg/L)	Hardness (mg/L)
Upstream (Sinclairville Bridge)					
Maximum Value	961	375	244	10.4	667.5
Mean Value	488	69	127	6.6	281
Minimum Value	132	2.2	45	4.4	131
Downstream (Bridge S. of Welland Airport)					
Maximum Value	492	460	146.1	16.0	284
Mean Value	331	81	106	10.9	182
Minimum Value	123	1.2	38	5.4	56

MAJOR CATIONS AND ANIONS

Parameters	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
Upstream (Sinclairville Bridge)								
Maximum Value	-	-	63.1	185	132.8	8.68	.243	576.8
Mean Value	-	-	22.6	76.8	45	1.43	.044	147
Minimum Value	-	-	10.2	32.25	4.45	.006	.004	22.78
Downstream (Bridge S. of Welland Airport)								
Maximum Value	35.6	11.4	24.3	73.8	85.25	5.87	0.260	143.9
Mean Value	14	6.4	14	48	26	1.74	0.100	71
Minimum Value	4.0	1.4	4.6	10.0	7.1	.005	.004	17.5

NUTRIENTS

Parameters	Ammonia-Nitrogen (mg/L)	TKN (mg/L)	Total Phosphorus (mg/L)	Nitrate-N (mg/L)	Nitrite-N (mg/L)	Total-N (mg/L)	B.O.D. (mg/L)
Upstream (Sinclairville Bridge)							
Maximum Value	.640	6.50	.930	8.68	.229	12.11	6.8
Mean Value	<.095	1.12	.183	1.43	.031	2.64	< 1.9
Minimum Value	.004	.21	.013	.006	.002	0.44	0.2
Downstream (Bridge S. of Welland Airport)							
Maximum Value	.910	8.00	0.810	5.87	.213	13.95	7.1
Mean Value	<.152	1.50	.230	1.74	.053	3.25	2.0
Minimum Value	.004	.20	.010	.005	.002	0.46	0.4

TABLE 3.16

HISTORICAL DATA SUMMARY: MOE MEASUREMENTS AT THE BRIDGES AT SINCLAIRVILLE AND SOUTH OF WELLAND AIRPORT, 1978-86

(Continued)

BACTERIOLOGICAL

Parameters	Total Coliform (per 100mL)	Fecal Coliform (per 100mL)	Fecal Streptococci (per 100mL)	Background Coliform (per 100mL)
Upstream (Sinclairville Bridge)				
Maximum Value	121 006	13 600	8 400	840 000
Mean Value	8 626	963	1 298	99 389
Minimum Value	40	10	4	900
Downstream (Bridge S. of Welland Airport)				
Maximum Value	152 000	2 700	10 600	800 000
Mean Value	8 240	379	919	70 644
Minimum Value	100	4	10	940

TRACE CONSTITUENTS - HEALTH

Parameters	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Cyanide (mg/L)	Lead (mg/L)	Mercury (ug/L)
Upstream (Sinclairville Bridge)						
Maximum Value	0.013	0.03	0.2	0.11	0.043	0.06
Mean Value	0.003	0.001	0.01	0.06	0.008	0.04
Minimum Value	0.001	0.0001	0.001	0.01	0.003	0.03
Downstream (Bridge S. of Welland Airport)						
Maximum Value	0.001	-	-	-	0.004	-
Mean Value	0.001	-	-	-	0.004	-
Minimum Value	0.001	-	-	-	0.004	-
	(one sample)				(one sample)	

TRACE CONSTITUENTS - AESTHETIC

Parameters	Aluminum (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Phenols (ug/L)
Upstream (Sinclairville Bridge)							
Maximum Value	41.0	0.04	48.0	0.7	0.11	0.12	4.2
Mean Value	4.8	0.01	5.1	0.29	0.008	0.017	<1
Minimum Value	0.54	0.001	0.7	0.02	0.001	0.003	-
Downstream (Bridge S. of Welland Airport)							
Maximum Value	6.2	0.006	16.0	0.53	0.008	0.031	4.0
Mean Value	5.05	0.005	4.3	0.128	0.008	0.022	<1
Minimuim Value	3.9	0.005	0.9	0.03	0.008	0.014	0.2
	(two samples)	(two samples)					

as chloride show widely varying values probably caused by a combination of events like low flow, or road salt inputs in periods of high flow in the cold months.

These observations are consistent with our understanding of the nature of the Welland River overall. At Wellandport and at the Welland Airport, the river can be considered to be like a long narrow lake. It is not expected to reflect the irregular inputs of runoff in the way that the Sinclairville station does. For these reasons, the comparisons will be made on the basis of the Welland Airport station. The exception is the priority organics for which only Sinclairville historical data is available.

3.6.3.1 General Chemistry

The general chemistry parameters were considered using the same grouping of parameters as is used for the discussion on the results produced in this study (see Appendix K, Tables K2, K3 for comparison with MOE historical data). The commentary on these parameters including concentration ranges encountered is identical to that produced for the current results (this study). It is more useful to consider this commentary along with the results produced by this study than to consider it here.

The min-mean-max data reproduced in Table 3.16 shows some extreme values that warrant an additional comment. The dissolved oxygen minimum reading of 1.8 mg/L is a single occurrence reflecting a special circumstance (undefined) in the river. Only one other datum in almost nine years of data collection was less than 4 mg/L, the lower end of the acceptable range for dissolved oxygen. Similarly, only two data exceed 250 FTU (Note: 1 FTU = 1 NTU) in the turbidity data set. This is the level of "good" raw water quality for drinking purposes.

3.6.3.2 Nutrients

As with the General Chemistry above, the nutrient parameters exhibit the same behavior (concentration range and dynamics) in the historical data as in the data collected for this study. The historical data provide a larger set of data with which to assess seasonal changes in these parameters. All the data available are used to describe the behaviour of these parameters but as before this commentary has been juxtaposed with the data collected for this study.

For this group of parameters the maximum values given in Table 3.16 do not need the same rationalization as above for some of the general chemistry parameters. Those parameters that frequently exceeded criteria (NH_3, TKN, Total P) the discussion is of limited value. For those that exhibited acceptable levels (NO_3, NO_2, BOD) there were no exceptions that required explanation.

3.6.3.3 Bacteriological

The historical data on bacteriological parameters does not cover all the parameters evaluated in this study. The total coliform and total background data are consistent with the data in this study.

These parameters are described by data that have to be viewed with an understanding of the way the analysis is performed and the precision of the data. The data say no more than the fact that the Welland River is contaminated by bacteria and any use would have to carefully consider disinfection. The data are highly variable showing no seasonality.

3.6.3.4 Trace Constituents

The historical data do not contain much information on trace constituents of a health or aesthetic concern. Information that is summarized in Table 3.16 is from limited sampling programs.

Some data on iron and phenol are available. The iron data show typically high total iron levels characteristic of waters like these draining soil types found in Niagara Region. Levels in the mg/L range exceed the aesthetic limit of 0.3 mg/L established for iron. Phenols often approach or exceed the aesthetic limit of 2 ug/L. Later data likely reflect a change in analytical methodology but remain typical of natural surface waters receiving inputs from streams containing decaying vegetation.

Some additional data were available from the Sinclairville station. Cadmium and mercury were analyzed for at this site. Levels encountered were all within drinking water limits. Chromium was detected occasionally above criterion levels; this is a common trace metal usually encountered as a low valent hydrous oxide (like iron) and is part of the turbidity load in a stream sample.

3.6.3.5 Priority Organics

Priority organics data were not obtained by the MOE for the Welland Airport Station. However, limited data are available from the Sinclairville station. At this latter station, data have been collected since 1981 on pesticides and heavily chlorinated aromatics.

At Sinclairville traces of up to 15 ng/L of benzene hexachloride (BHC) in three isomeric forms were detected. These chemicals alpha-, beta-, gamma-, BHC are components of pesticides

for the control of insect pests on animals and crops. It is not surprising that it is found in water in an agricultural area.

One incidence of PCB detection was encountered at Sinclairville. This single occurrence at 0.160 ug/L was unique in a data set spanning 5 years where all other (monthly) data was non-detectable at less than 20 ng/L.

3.6.4 1986 WATER QUALITY - WELLAND RIVER

The observed water quality in the Welland River for 1986 is detailed in this section. A summary of the samples taken and analysis performed is outlined in Figure 3.10. Included in this figure are the sampling dates for all samples.

The presentation of the data is in tabular form in Appendix K. The data tables are preceded by Table K1, which is a glossary of chemicals for the tables to follow. The data are organized consistent with the foregoing discussion on parameter selection, detection limits and guidelines and criteria. For the Welland River, the following tables have been organized:

General Chemistry - Wellandport(W)	W	TABLE K2
- Pearson Bridge(P)	P	TABLE K3
Nutrients + Bacteriological	W	TABLE K4
	P	TABLE K5
Trace Constituents	W	TABLE K6
	P	TABLE K7
Priority Organics - Volatiles	W	TABLES K8 and K9
	P	TABLES K10 and K11

- Acid Extractables	W	TABLE	K12
	P	TABLE	K13
- Base Neutrals	W	TABLES	K14, K15 and K16
	P	TABLES	K17, K18 and K19
- PAH, PCB	W	TABLE	K20
	P	TABLE	K21
- Pesticides and Herbicides	W	TABLES	K22 and K23
	P	TABLES	K24 and K25

Sampling at the Welland River sites in general corroborated and expanded the MOE findings. As well as the parameters tested by the MOE, priority pollutants and pesticide concentrations were measured. These data are assessed below.

As part of the quality control program used in this study, field blanks prepared in the field are submitted to the laboratory. The data obtained from analysis of these field blanks are listed in Tables L5 through L15. In the discussion that follows, a notation is made when a parameter is detected in the river and in the corresponding field blank. Detection of the parameter in a field blank is an indication of sample contamination or analytical bias which should be considered in assessing water quality.

Location	Sampling Date	G	N	B	T	Pr	Ps
		Regular Samples					
SITE STATION 3A (SUCKER CREEK)							
Winter Low	86.02.14	••	••	••	••	••	••
Freshet	86.03.11-14	••	••	••	••	ns	ns
Spring	86.04.02	••	••	••	••	•	•
Spring A	86.04.29	••	••	••	••	ns	ns
Summer Storm	86.08.07	••	••	••	••	•	••
Summer Low	86.09.03	nf	nf	nf	nf	nf	nf
Fall A	86.10.08	••	••	••	••	ns	ns
Fall	86.11.11	••	••	••	••	••	••
Fall Storm	—	ns	ns	ns	ns	ns	ns
SITE STATION 2 A (9-C CREEK)							
Spring A	86.04.29	••	••	••	••	••	••
Summer Storm	86.08.07	••	••	••	••	••	••
SITE STATION 4A (WELLANDPORT)							
Winter Low	86.02.14	••	••	••	••	••	••
Spring	86.04.02	••	••	••	••	•	•
Summer Low	86.09.03	••	••	••	••	••	••
Fall	86.11.11	••	••	••	••	••	••
SITE STATION 4B (PEARSON BRIDGE)							
Winter Low	86.02.14	••	••	••	••	••	••
Spring	86.04.02	••	••	••	••	••	••
Summer Low	86.09.03	••	••	••	••	••	••
Fall	86.11.11	••	••	••	••	••	••
SNOW							
Winter	86.02.28	••	••	ns	••	ns	ns
SEDIMENT							
Summer	86.09.03	••	••	ns	••	••	••

LEGEND

G- General Chemistry
N- Nutrients
B- Bacteriological
T- Trace Elements
Pr- Priority Organics
Ps- Pesticides
• Sample Taken
•• Results Recieved
ns- No Sample
nf- No Flow
na- Not Applicable

QA/QC SAMPLES

G	N	B	T	Pr	Ps
••	••	••	••	•	•
••	••	••	••	••	••
••	••	••	••	••	••

↑ na ↓

••	••	ns	••	••	••

ns = no sample

nf = no flow

OWMC Ontario Waste Management Corporation

DILLON

SUMMARY OF SAMPLES TAKEN AND LAB ANALYSIS PREFORMED

Figure 3.10

3.6.4.1 General Chemistry

The data on the general chemistry parameters for the Welland River for 1986, presented in Tables K2 and K3, are typical of a stream in an agricultural area subject to high flows in the runoff periods and sluggish flow in dry weather months.

The temperatures measured at the two sites in the Welland River are of the order expected for surface waters. Temperature variations are seasonal, as expected, being much lower in the winter than in summer. As discussed in Appendix I, the Ontario water quality criterion for temperature addresses the maximum allowable temperature change caused by a discharge. Background temperature data will be useful in determining the allowable discharge temperatures at various times of the year.

The pH of the water fell within the acceptable range (6.5 - 8.5) during all sampling episodes. The pH variation through the year should be reviewed along with the alkalinity data. The water alkalinity starts the year at the low end of their ranges reflecting natural processes and mildly acidic precipitation that results in a net decrease in alkalinity in winter and early spring. Once the growing season is underway, net acid consumption through living processes and the decrease in inputs of fresh precipitation water causes the alkalinity and pH to rise.

The total load of dissolved and suspended material in the river water is provided by data listed under conductivity, total residue, major cations and anions and calculated total salt content. It is apparent the Welland River contains dissolved salts in the 300-400 mg/L range through the year. (The winter sampling at Pearson Bridge is anomolously high.) The concentration is higher in the dry weather months again reflecting low inputs of fresh water. The dissolved salts reflect the region's

geology with calcium, magnesium, carbonate, and sulphate species predominating. The water is hard, bordering on being a "poor" source for drinking water as a result. The sulphate level falls well within natural ranges and would not limit the use of the river water. Sodium levels are not high enough to limit this river as a source of drinking or irrigation water (sodium is <20 mg/L and the sodium adsorption ratio (SAR) <<4). Potassium levels are influenced by fertilizer runoff. The levels are higher in the spring when fertilizers are applied. The chloride-bromide-fluoride levels reflect the summer low flow character with slightly higher levels. None of these anions would limit the potential use of the river water; fluoride levels are well below the 2.4 mg/L level set for drinking water use in Ontario and also below the 1.2 mg/L level set elsewhere for fluoride.

The data on turbidity and total organic carbon are indicative of the turbid appearance of the Welland River. The turbidity is not particularly high, in fact the Welland River falls into the "good" category as a raw water source for drinking water based on this parameter. It carries more organic carbon than is acceptable for drinking water but a simple water filtration system would bring this parameter into conformance with the drinking water criteria.

The dissolved oxygen was always within the acceptable range of 4-8 mg/L. The lowest levels were encountered in the summer samplings typical of enhanced biological activity in the river at that time. In the cool weather less demand exists for dissolved oxygen, and the oxygen solubility in water is higher at lower temperature, both factors contributing to higher observed levels at these times.

3.6.4.2 Nutrients

Nutrient data for the Welland River provided in Tables K4 and K5 indicate that the Welland is overloaded with nutrients typical of a slowly moving water course potentially receiving runoff from human and animal waste disposal systems. In general the waters of the Welland River fail to meet the provincial water quality objectives for nutrients. This failure makes it a Policy 2 (MOE, 1984a) stream subject to water quality improvements.

The ammonia levels in the Welland River approach or exceed guideline levels for un-ionized ammonia. (Note, the data in Tables K4, K5 have to be considered along with pH data in Tables K2, K3). The data collected for ammonia are consistent with the historical data on ammonia (Section 3.6.3) but are insufficient in number to demonstrate seasonal trends. However, taken with the historical data, the seasonal variation can be discerned where ammonia levels are higher in the winter than in the summer. Usually, the river's pH is such that the high ammonia occurrences correspond to low pH occurrences which protects the river from un-ionized ammonia exceedences. However, the historical data does reveal occurrences at a frequency in the order of once a year when ammonia criterion is exceeded.

Total Kjeldahl Nitrogen (TKN) exhibits behaviour similar to ammonia. Historically, it is higher in the cool months although this trend is difficult to discern from the limited data collected in 1986. Ammonia and TKN values are related because they participate in the natural nitrogen cycle in aquatic systems like the Welland River. Both the data from this study and the historical data show that the Welland River always contains TKN in excess of the criterion value of 0.15-0.20 mg/L. Raw water to be treated for drinking purposes would have to address removal of the TKN values to avoid taste complaints from consumers. Fortunately, simple traditional coagulant, sedimentation and filtration techniques will remove material causing high TKN values.

The nitrite in the Welland River also participates in the nitrogen cycle and exhibits a similar seasonal pattern with high values in the cool weather. Nitrite is closely related to nitrate through one of the equilibrium in the nitrogen cycle. Both of these parameters consistently report below the criteria for drinking water. All of these nitrogen parameters are typical of waters in agricultural areas where inputs from animal and human wastes are expected. Animal waste inputs can be fairly direct; human waste inputs are expected even from septic systems which can produce inputs through ground water discharges to surface water.

Total phosphate levels are also above criteria levels for the protection of river systems like the Welland River from algal growth. The phosphate appears to be tied to participate matter because soluble phosphate is not detected. Total phosphate always exceeds the 0.1 mg/L criterion for flowing rivers and the 0.025 mg/L criterion for lakes and reservoirs. The Welland River often behaves like a long narrow lake so that the potential for algal blooms is supported by the total phosphorus levels.

The biochemical oxygen demand (BOD) from this study showed two exceedences of the 10 mg/L criterion for "polluted" water. In contrast, the historical data showed no such exceedences. However, the BOD data for the April 1986 sampling was questionned in the QA/QC program and is probably incorrect data. On balance, it is believed the Welland River has not exceeded the criterion for BOD for the time period covered by the historical data and the data developed by this study.

3.6.4.3 Bacteriological

The data from bacteriological samplings (Tables K4 and K5) support the conclusion that the Welland River is a fairly polluted river because of inputs from human activity, either directly or through

agricultural practices. Levels of total and fecal coliforms, fecal streptocci and background bacteria observed suggest that any domestic use of this water should be subject to strict disinfection treatment. Contrary to MOE data (Section 3.6.3.2), fecal coliform counts predominate, pointing to human sources for the contamination, perhaps owing to the proximity of the sampling site to human settlement adjacent to the river at Wellandport.

The water also is unsuited to recreation uses in the summer at both Welland River stations. The unsuitability persisted into the fall at Wellandport, again, consistent with that sampling point being closer to human activities.

While the sampling did not extend over a series of samples, there are enough indications that the Welland River would be considered "impaired" on the basis of the bacteriological parameters (MOE, 1984a)

3.6.4.4 Trace Constituents

The Welland River is confirmed as a Policy 2 Watercourse (area where water quality does not meet the objectives and where MOE will not permit further degradation of water quality with new or expanded discharges (MOE, 1984a) by data on the occurrence of trace constituents at levels above acceptable criteria. In particular levels of copper, cyanide and sulphide exceed freshwater aquatic criteria and aluminum, iron and manganese exceed the aesthetic criteria for drinking water. These constituents tend to enter the water from bottom sediments. Rain data for this area (ORF, 1987) indicates that precipitation will also contribute to the levels affected. Data are provided in Tables K6 and K7.

Arsenic was detected twice at both locations on the Welland but the drinking water water criterion (50 ug/L) was not approached. Extrapolation of experimental data on lab animals has led to the USEPA suggesting a 2.2 ng/L (USEPA, 1980) level for protection against incremental cancer at the risk level of 1 in 10^6 (see criterion statement on arsenic, Appendix I). This is

the first of many such extrapolations that produce criteria level below the detectability level of modern analytical technology. The criteria are used for information only, as in many cases they appear to be overestimates of the ultimate toxicity.

No detectable cadmium was found in any Welland River samples. Again, the detection limit is 1 ug/L, compared to the water quality objective of 0.2 ug/L (MOE, 1984a)

One chromium occurrence was noted. It was well below any level of concern and also showed up in the field blank for that sampling date.

Cyanide was detected in almost half the samples collected from the Welland River. Although they were all well within the drinking water guidelines, they exceeded the Provincial guideline for protection of aquatic species. Sulphide was similarly detected in a number of samples at levels exceeding those required to protect aquatic species. For both cyanide and sulphide, the detections occurred in the colder months. It is plausible that in the absence of biological activity there can be re-entrainment of reduced material from bottom sediments. It appears this is occurring in the Welland River. Cyanide and sulphide levels are highest in winter and fall off to non-detectable levels by summer reflecting the lower level of activity among aquatic lifeforms in the winter months. This activity normally oxidizes these reduced species to harmless products.

Lead was detected once, in the spring, in both Welland River samples. It was at a level well below the criteria for human and aquatic life protection.

Mercury was not detected in any Welland River samples.

Among the trace constituents with a primary aesthetic concern phenol and zinc were either non-detectable or were present at very low levels. Aluminum, iron and manganese all exceed the aesthetic drinking water standards. These metals are characteristically associated with suspended material and would be quite efficiently removed with good filtration.

Copper did not occur at concentrations affecting aesthetics of drinking water. However, it was almost always present at levels above those suggested for the protection of aquatic life. It is noteworthy that the (USEPA, 1980) levels for copper, which take into account hardness, are less stringent and in fact suggest that the levels encountered here for copper are not a concern (see Appendix I for the copper criterion statement).

3.6.4.5 Priority Organics

Data on priority organic analyses done on Welland River water are given in Tables K8 through K25. Only a few parameters were detected at the trace level. Fewer still, namely two examples of phthalates, were quantified above the detection limit.

Among the volatile organics analyzed for, only trace quantities of chloroform, benzene, toluene and xylenes were noted (Tables K8 to K11). Traces are reported by the labs as indications of the possible presence of the compound. The presence of this group of chemicals (excluding chloroform) and the occurence in both samples drawn from the Welland suggests that it was more than a random sampling/analysis artifact. Further, these are all related in their use (petroleum products, eg. gasoline) so it is not unexpected that they were detected. The criteria suggested for these compounds are not exceeded even if the "trace"

indication is assumed as the "detection limit". The benzene criterion for 1 in 10^6 incremental cancers (0.66 ug/L) is exceeded at the detection level but that level is one of the ultra-conservative values suggested by the USEPA (USEPA, 1980).

It should be noted that the volatile organics detected in the river samples were detected in the field blanks for the corresponding sampling dates, see Tables L8 and L9. Other volatile organics were also identified in the field blanks. The detection of these organics in both the samples and the travel blanks may indicate contamination of the samples during transportation or at the lab, contamination of laboratory detection apparatus or bottle contamination. No correction of the data for field blanks was made. The blank data does point out the difficulty in interpreting the occurrence of low levels of trace organics in samples obtained and handled in this manner.

No acid-extractable or PCB/PAH class compounds were detected see Tables K12, K13, K20, K21.

Among the base-neutral compounds, Tables K14 to K19, two examples of phthalates, di(2-ethylhexyl)phthalate (D2EP) and dibutylphthalate (DBPH) were detected at levels up to 270 ug/L and they were found above detection levels in most samples. The phthalate levels encountered are not of a particular concern for human health but Ontario has set criteria for these chemicals at 4 ug/L for DBPH and 0.6 ug/L for D2EP. Other phthalates should be below 2 ug/L in Ontario; one other occurrence, diethylphthalate, was encountered in the Welland at a level of 8 ug/L (Pearson Bridge, September).

The phthalates which were detected in the river samples were also detected in the field blank samples, Tables L11 to L13. Due to their ubiquitous nature they are nearly unavoidable in the sampling process and analytical procedures carried out in the laboratory.

One other trace occurrence, that of hexachlorobenzene at both stations on the same day is worth noting K15 and K18. It was not detected in the field blank. The occurrence at the detection level presents a problem in assessing the importance of this observation since criteria for this chemical are less than the detection limit. It suggests further investigation using more sensitive techniques (if they are indeed available).

One occurrence of the pesticide aldrin was noted at the trace level in the winter sample at Pearson Bridge. Even at the trace level of detection this occurence is not a concern. Aldrin was also detected in the field blank for this date indicating that its presence may be due to contamination during sampling, transportation or at the laboratory.

The herbicide atrazine was found in both monitoring stations on the Welland River. Atrazine is a widely used herbicide used on corn crops and for control of roadside weeds. Its presence is expected in surface waters in agricultural communities. As outlined in Appendix I, it is of low toxicity and degrades rapidly in the environment.

No analysis was obtained for parameters indicated by "n/a" in Tables K8 through K25.

3.6.5 1986 SEDIMENT QUALITY

Sediment composition can reflect the recent history of a water body and its sources. Contaminants may be brought from upstream and deposited, or local inputs may be concentrated (biologically, for example) and precipitate. Alternatively, high flow events may remove sediment, depositing it downstream and replacing it with material (from upstream) or from the watershed. Sampling of sediment from the Welland River at both Wellandport and at the Pearson Bridge was undertaken to identify the chemical species present in the stream beds both upstream and downstream of the proposed surface water outfall. This is intended to establish baseline concentrations of substances of concern.

If changes occur in future, a data base for upstream and downstream locations will facilitate identification of possible site influences. Where there is no site influence, the relationship of the upstream and downstream compositions would be expected to be predictable from baseline and ongoing monitoring. Site effects would be discerned and quantified by observing deviations from predicted and explainable behaviour.

Sediment quality was determined at two stations on the Welland River as discussed above. Sampling took place on 3 September, 1986 and both sediment samples were analyzed for all chemical contaminants determined for surface water. The sediment quality data is detailed in Tables K26 - K31.

Sediment quality at Wellandport and Pearson Bridge is very similar. All contaminant levels are of the same order of magnitude. Concentrations of major metallic and other inorganic contaminants tend to be slightly lower at Pearson Bridge than Wellandport, but well within the variability normally expected. Iron and aluminum are present at higher levels in the percentage

range as is expected because their oxides are major components of soils and sediments. Trace elements are present at levels typically found in Canadian sediments in industrial areas.

The river sediments are characteristically high in other common metals like potassium, magnesium and calcium. The soil is high in sulphate, fluoride and chloride salts which is typical of Southern Ontario sediments. The sediments are also rich in organic nitrogen and ammonia which are somewhat typical but could also be a result of fertilizer deposition on the sediments.

There is no indication of industrial chemical or priority organic contamination in the Welland River sediments indicating again that they have not been contaminated by industrial pollution.

3.6.6 WATER QUALITY - SNOW

Snow sampling took place on 28 February, 1986. Snow depth in open fields was relatively low, since a thaw had occurred in mid-January. Considerable accumulation had melted during the thaw, and relatively small snowfalls occurred in late January and February. Therefore, the accumulation represented the residue from early winter remaining after thaw and subsequent snowfalls.

Samples were taken at the OWMC site since it was accessible and did not appear to be significantly different from the downwind area. Samples were obtained from four locations indicated on the site map in Figure 2.1. At these locations there were significant accumulations, free of wind blown soil. The four samples were composited in the laboratory. Results of analyses are included in Table K32. The snow did not contain high levels of contaminants. Almost all parameters are within water quality objectives, criteria, guidelines and standards for domestic, agricultural and

industrial water use. The pH, at 6.2, is slightly lower than the Ontario Drinking Water Objectives. However, since the snow has a very low dissolved salts concentration, the presence of even minute quantities of airborne acid species in the snow would lower the pH.

Ammonia and nitrate (nutrient species) are the major constituents in the snow. Their presence may be due to agricultural activity.

3.6.7 WATER QUALITY - SUCKER CREEK AND 9C CREEK

Sucker Creek and 9C Creek were sampled to obtain water quality data during typical seasonal conditions and during periods of high runoff (storm events). The purpose was to obtain data for the broadest possible range of conditions. The Sucker Creek sampling program included 2 runoff events, the spring freshet and a summer storm, with three samples each. As well 5 seasonal "normal" samples, winter low, early spring, late spring, early fall and late fall, were collected. No summer low flow sample was collected because Sucker Creek dried up at this time.

9C Creek was sampled twice to provide some data on the direct surface drainage from the site.

In the dry season, the flow in the creeks ceases and in places they dry up completely. No samples were taken of non-moving water, since samples would not represent a significant water flow. This is signified by "nf" on Figure 3.10.

The overall characteristics of the creek water are similar to those for the Welland River. The data are organized in Tables K33 through K56 of Appendix K with the pairings as before under

General Chemistry, Nutrients + Bacteriological, Trace Constituents and Priority Organics. As before, all of the priority organic data were less than detected except as reported here.

3.6.7.1 General Chemistry

General chemistry data collected for Sucker Creek and 9C Creek are presented in Tables K33 and K34. As for the Welland River, the results are typical for waters from an agricultural area during periods of high and low flow.

As expected, temperatures in both creeks are very close to temperatures in the Welland River and vary seasonably. Temperatures in Sucker Creek remain relatively constant through both the spring freshet and the fall events.

Measurements indicate that the pH of these waters are within the acceptable range of 6.5 to 8.5. pH is higher in the summer months than in winter. As discussed in Section 3.6.6.1, the seasonal variation of pH should be considered along with alkalinity which also tends to be higher in summer than in winter.

Dissolved oxygen is almost always above the MOE's minimum acceptable range of 4-8 mg/L. The observed values are higher than those for the river, probably due to aeration occurring in the small stream with a higher ratio of surface area to volume.

The total dissolved solid load on Sucker Creek under normal flow conditions ranges from 250-350 mg/L. During high flow events values of 500-700 mg/L are observed from surface runoff. These values would not limit the use of creeks as water sources for agricultural use. Calcium, magnesium, chloride and sulphate are the predominant dissolved species. Potassium is highest during the spring freshet because of fertilizer runoff. Sodium levels in 9C Creek were higher than those found in the Welland River.

Conductivity is closely related to the load of dissolved species in the water. The conductivities observed are as expected in surface waters and are comparable to observations for the Welland River. Higher values are observed during the runoff events.

The turbidity of the creeks is comparable to levels observed in the Welland River and like the river would be classified as good raw water sources. As expected, higher values are observed during the freshet and again during the summer storm.

No bromide was detected in either creek. Under normal flow conditions, chloride is lower in the creeks than in the river. The fluoride levels observed would not limit either creek as a source of water for domestic or agricultural use.

Levels obtained for total organic carbon (TOC) indicates a polluted watercourse. Organic carbon content is higher in the summer than in the winter probably due to low flow conditions.

3.6.7.2 Nutrients

Nutrient data for the creeks are presented in Tables K35 and K36 of Appendix K. Under normal flow conditions, the nutrient load on Sucker Creek is of the same order as found in the Welland River. The nutrient load on 9C Creek tends to be higher than either Sucker Creek or the Welland River. 9C Creek has little base flow component at any time during the year so that runoff containing nutrients comprise the water quality whenever flow occurs.

During the spring freshet (March sampling at Sucker Creek) levels of ammonia and nitrates are elevated as a result of runoff from decaying material. No nitrites were detected in any samples from Sucker Creek and only in one sample in 9C Creek. Nitrates

are particularly high during the summer storm event, possibly reflecting the washing off of nitrogen species during the storm event.

Amine nitrogen, indicated by TKN, is higher in the creeks than in the river and in all samples, exceeds the drinking water criterion of 0.2 mg/L. Based on levels of total phosphorus measured in the creeks, algae growth would be expected. Both these nutrient parameters reflect the same situation as described above; nutrients in the form of decaying organic matter are being washed off the land.

Biochemical Oxygen Demand (BOD) data are higher for the creeks than for the Welland River. These data again confirm the polluted nature of the waters and the load of pollutants being washed off the land into these streams.

3.6.7.3 Bacteriological

Bacteriological indicators confirm that these creeks are polluted and that levels found in the creeks are generally higher than those found in the Welland River. The levels are highest during the freshet and during the summer storm as a result of surface runoff. These bacterial indicators reflect the high input of runoff from agricultural activities in the area.

3.6.7.4 Trace Constituents

Trace constituent data for Sucker and 9C Creeks are presented in Tables K37 and K38. At various times, particularly in the spring, levels of trace constituents in both creeks are in excess of acceptable criteria. Like the Welland River, they are classified as Policy 2 watercourses (areas where water quality does not meet the objectives and where MOE will not permit further degradation of water quality with new or expanded discharges (MOE, 1984a)).

Levels of cyanide, sulphide, copper, iron, manganese and zinc tended to exceed Ontario's objectives for the protection of the aquatic habitat in Sucker Creek. No cadmium or sulphide was detected in the 9C Creek samples and in general levels of these contaminants were lower in 9C Creek than in Sucker Creek.

Arsenic was detected at very low levels in many of the Sucker Creek samples and in the spring sample from 9C Creek. Cadmium was detected at levels in excess of aquatic habitat criteria in two samples from Sucker Creek. No cadmium was detected in 9C Creek, nor was any chromium detected. Chromium was detected in Sucker Creek on four occasions but at levels much below levels of concern. As well, lead was detected but at levels well below levels of concern. These occurrences of trace constituents did not correlate with high flow events but occurred randomly among the event and routine sampling episodes.

Levels of aluminum, copper, iron, manganese and zinc are particularly high during the spring freshet and are correlated to the elevated turbidity. They also peaked during the freshet. These results are not unexpected since these parameters tend to be associated with soils and sediments and would be introduced into the water during runoff and would be closely related to turbidity. This is confirmed by the high levels of these contaminants identified in area sediments.

Phenol was detected in Sucker Creek twice during the freshet and in the spring in 9C Creek. The levels are above Canadian drinking water standards but well below aquatic toxicity criteria set by the USEPA (USEPA, 1980).

3.6.7.5 Priority Organics

Data collected on priority organics in Sucker Creek and 9C Creek are presented in Tables K39 through K56 of Appendix K. As in the Welland River samples, few organics, mainly phthalates, were detected at a quantifiable level.

No volatiles were detected in 9C Creek samples. As in the Welland River, chloroform, benzene and toluene were detected in Sucker Creek at trace levels in the fall. As discussed in Section 3.6.4.5, these organics also showed up in the field blank for that date and their detection is possibly due to contamination either during or after sampling. Chloroform was also detected at a level of 0.1 ug/L (below the normal detection limit) in the winter low flow sample from Sucker Creek.

No acid extractable organics were detected in any of the creek samples.

Within the base/neutral extractable group, di(2-ethylhexyl) phthalate (D2PH) and dibutylphthalate (DBPH) were detected in nearly all samples collected. These were also detected in river samples. A trace of diethylphthalate (DEP) was also detected in the Sucker Creek fall sample. Hexachlorobenzene (HCB) was detected at low levels in both creeks as well as in both river samples from the winter sampling. A trace of 1,2,4-trichlorobenzene (124TCB) was detected in 9C Creek during the summer storm.

Among the pesticides beta-BHC was detected once in Sucker Creek. Atrazine was detected at both Sucker Creek and 9C Creek. Levels were highest in the summer reflecting local use and runoff to surface water.

No analysis was obtained for parameters indicated by 'n/a' in Tables K39 through K56.

3.6.8 DIOXIN ASSESSMENT

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are produced in trace amounts by some chemical processes and incineration, see Appendix I. PCDDs and PCDFs are not routinely found or are expected to be found in Ontario surface waters remote from chemical industries. However, because the OWMC facility will incorporate an incinerator for the destruction of chemical wastes, the study team felt it was necessary to determine if background concentrations of PCDDs were present in existing Welland River water.

Samples were analysed for PCDD and PCDF both in water and sediment collected at Pearson Bridge on 3 September 1986. The results of these analyses are shown in Table K57. No PCDFs or PCDDs were detected in the sediments. However, 2 ng/L of tetrachlorodibenzodioxin (2,3,7,8-TCDD) was identified in the water at Pearson Bridge. Although only a very small concentration was identified, the 'no adverse effect' level for 2,3,7,8-TCDD is 0.7 ng/L (NRC, 1977), which is lower than the levels found at Pearson Bridge. The results are somewhat anomalous, however, as dioxins are hydrophobic and tend to absorb on sediment rather than remain in water, and no dioxins were identified in the sediment collected on the same day at the same river station. However, the detection limits for the sediments (0.2 ug/L) is higher than for water (0.2 ng/L).

There is insufficient data to assess whether dioxins are a legitimate concern in the Welland River. Further dioxin sampling is recommended to confirm these results.

PART 2

PREDICTED IMPACTS, IMPACT MANAGEMENT AND MONITORING

PART 2 - PREDICTED IMPACTS, IMPACT MANAGEMENT AND MONITORING

CHAPTER 4
INTRODUCTION

4.1 REPORT FORMAT AND SCOPE OF WORK

The overall purposes of this report and the scope of work for the Phase 4B surface water studies are summarized in Sections 1.1 and 1.3 respectively. Part 1 of the Report (Chapters 1 to 3) concentrates on the environmental baseline conditions and summarizes the results of the streamflow and water quality monitoring program carried out during 1986.

Part 2 (this part), comprising Chapters 4 to 7, considers the assessment of impacts on the surface water features of proposed OWMC facilities and operations, proposes appropriate mitigative measures and recommends a long-term monitoring program for the surface water features necessary to assess actual impacts.

In the absence of any treated effluents discharging to local watercourses, water quality impacts for the construction and operational periods relate primarily to nuisance impacts such as

erosion and downstream sedimentation, as well as to possible deterioration in the Welland River water quality resulting from OWMC water takings and to the potential release of contaminated storm drainage to the Welland River. Other opportunities for surface water contamination (e.g. transportation spills into surface water and air emissions) are included in other studies (Environ, 1987). This includes potential contamination of ponds, cisterns and surface streams via the air pathway.

Water quantity impacts relate to the potential increase in peak flows and runoff volumes resulting from development of the site, together with the associated increases in flood levels in local watercourses and the Welland River. The impact of site flooding from off-site watercourses has been considered, together with the loss of use of surface water by virtue of stream diversion.

Chapter 4 (this chapter) is the introductory chapter to Part 2 and provides a brief description of the report format and outlines the design concept for the surface drainage system, together with the time horizons and the key surface drainage management features employed in the surface water impact assessment.

Chapter 5 summarizes the methods used for post-development flow calculations, for quantification of erosion potential and in the assessment of downstream impacts. Chapter 6 deals with the predicted impacts and their significance, while in Chapter 7, the impact management measures and options are discussed, together with recommendations for emergency response measures. Chapter 7 also outlines a recommended program for long-term monitoring.

4.2 TIME HORIZONS AND SURFACE DRAINAGE MANAGEMENT FEATURES

The relevant time horizons for the surface water analysis are briefly discussed in Section 1.4.2. Baseline conditions have been fully addressed in Part 1 of this report and provide the existing environmental setting against which the impacts of OWMC activities can be compared.

The impact assessment focuses on the periods of facility construction, operation and post-closure. A number of impact management measures, adopted by OWMC during the Phase 4A and 4B studies, are directly relevant to the surface water analysis. These are summarized in Section 2.2.1. Of particular importance to this study is the proposed segregation of surface drainage from the central operating area (COA) and the landfill area. All runoff from the COA will be collected and tested for contamination prior to release. If contaminated, this runoff will be pumped to the physical-chemical treatment plant. If uncontaminated, it will be directed to the storm water outlet from the site. Similarly, any potentially contaminated runoff from the operating area of the landfill will be dealt with in a similar fashion (Monenco, 1987a).

For the operational period, uncontaminated runoff from the COA will be pumped to the surface drainage system at a low rate and will not contribute to peak flows from the site. Consequently, only the landfill area will contribute to peak flows downstream during the operational period. After the facility has been decommissioned and the treatment facilities and associated works have been removed from the site, it has been assumed that the COA will be regraded to drain by gravity via the surface drainage system.

Flow and erosion calculations and the assessment of surface water impacts contained in this report relate to the periods of facility construction, operation and post-closure.

In this report, only the landfill surface drainage system is described in detail. The surface drainage system for the COA and associated on-site impacts are being addressed by Monenco Ltd. (1987b). However, the impacts of runoff from the COA on off-site surface drainage features have been considered herein.

4.3 OBJECTIVES OF SURFACE DRAINAGE SYSTEM

The principal objectives of the landfill area surface drainage system have been identified as follows:

i) No significant increase in peak flows (above existing conditions) through downstream lands or to the receiving stream (Welland River).

ii) Efficient drainage of the site area to minimize potential for infiltration and to ensure uninterrupted site operations.

iii) No flooding of land adjacent to the site resulting from construction of the perimeter berm.

iv) Ensure unrestricted conveyance of runoff from external areas around the site.

v) Minimize the amount of runoff entering the active landfill area.

vi) Minimize potential for increased erosion on-site and downstream.

vii) Minimize the amount of sediment leaving the site.

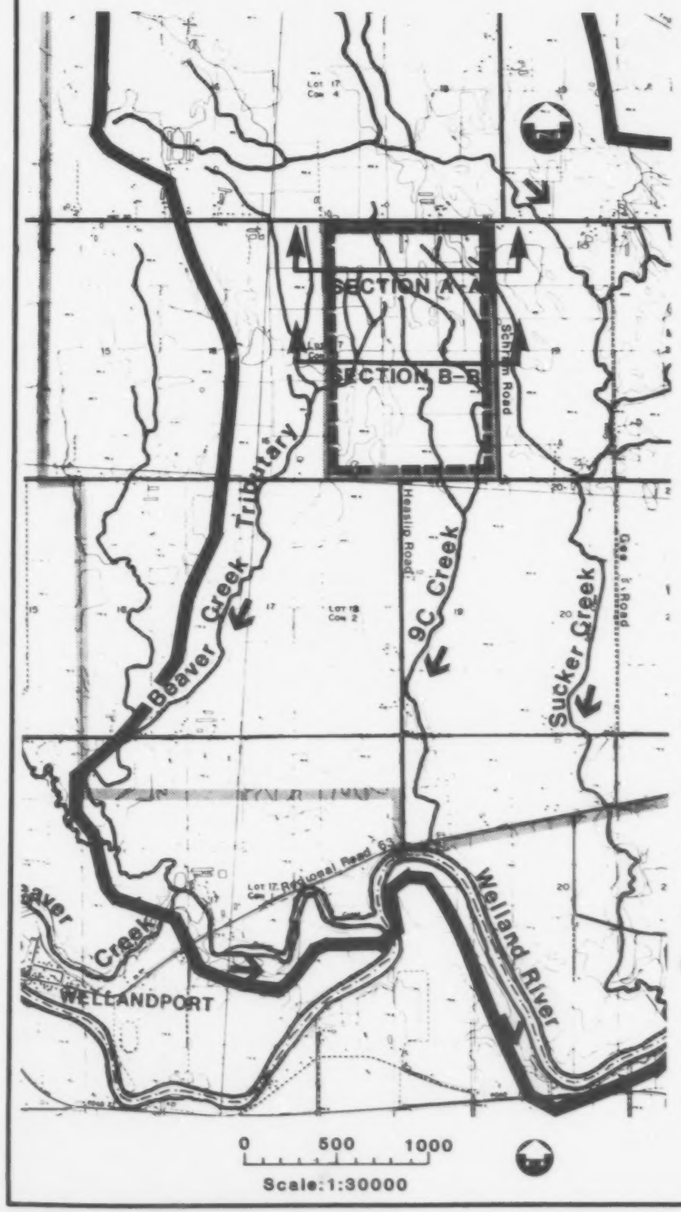
viii) Protection of water quality in off-site watercourses.

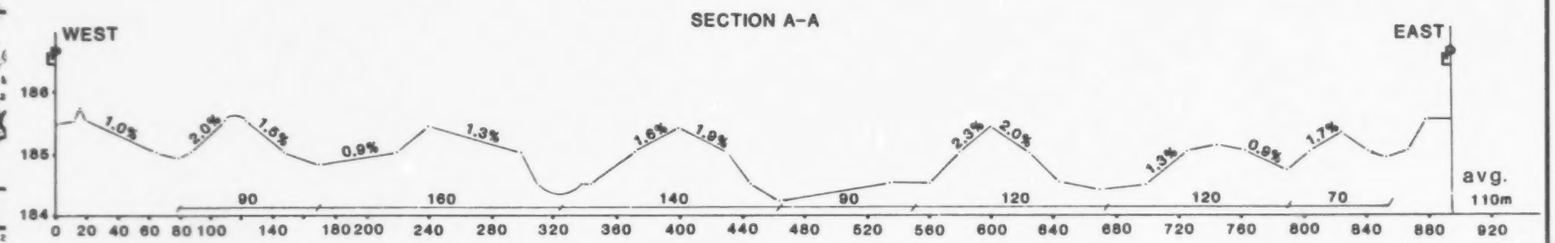
The design criteria and mitigative measures described in subsequent sections of this document have been developed to satisfy these objectives. They will also meet the requirements of the various regulatory agencies (Niagara Peninsula Conservation Authority, Ministry of Natural Resources, Township of West Lincoln).

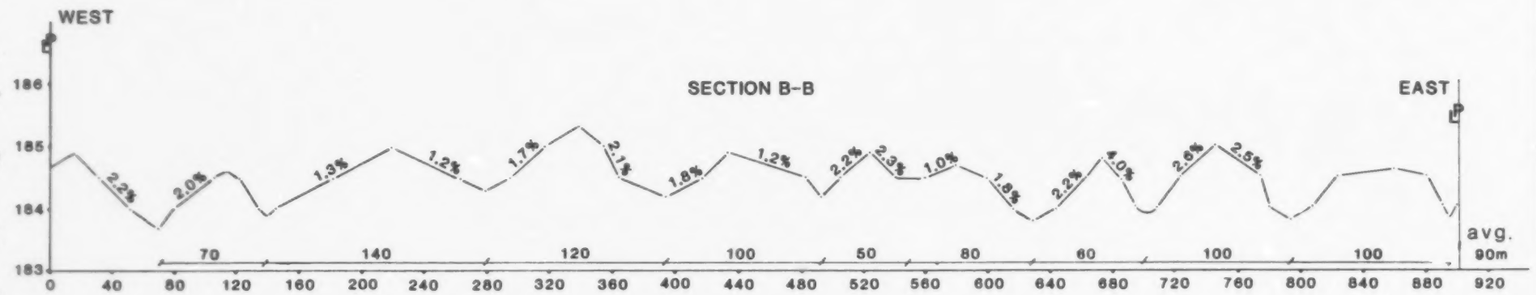
4.4 SURFACE DRAINAGE CONCEPT

During the Phase 4B studies, a practical surface drainage concept was developed for the landfill in cooperation with the hydrogeological consultant (Gartner Lee) and the engineering consultant (Monenco). The principal objectives of the landfill drainage system are the efficient removal of runoff from the site, minimizing the potential for infiltration and ensuring uninterrupted access for landfilling operations during and following precipitation/runoff events.

Hydrogeologic constraints require that the final ground elevations not differ appreciably from existing conditions to avoid increasing ground water mounding and infiltration. Consequently, significant mounding of the final cover to promote highly efficient shedding of surface water was not a viable alternative. Perimeter berming surrounding the site will also segregate external surface drainage from the internal drainage system.







NOTES:

1) Average swale separation distance = 100m.
2) Fluctuation in grade elevation across site =1-1.5m.
3) Select 2% overland flow slope for design.

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TYPICAL SITE CROSS SECTIONS

FIGURE 4.1

To define a final landform generally consistent with the existing ground profile, typical cross-sections of the site were analyzed to determine average swale separation distances and the overland slopes between swales. Two typical cross-sections are shown on Figure 4.1. These sections indicate an average swale separation distance of approximately 100 m and an overland slope of about 2%. The average elevation difference between the peaks and troughs of the swales ranges from 1 m to 1.5 m across the site. Accordingly, a micro-drainage system comprising a spacing of swales at 100 m and 2% overland slopes was selected for the final cover (see Figure 4.2 at back of this volume).

The swales will interconnect to perimeter ditches around the site and the COA to provide a continuous flow path to a common outlet at the south end of the site. The proposed site grading, in combination with the perimeter ditching, will provide a reasonably efficient surface drainage system, while at the same time satisfying the hydrogeologic requirement for maintaining near existing ground elevations. Significant increases in peak runoff from the completed landfill can be anticipated resulting from the provision of a continuous flow path for all surface runoff and the elimination of significant depression storage, which characterizes the existing topography.

Runoff from external areas, which currently drains through the site, will be diverted around the site (outside the perimeter berms), via external conveyances (ditches and/or storm sewers) and will outlet to existing watercourses or swales.

The proposed storm drainage system also comprises a landfill storm detention pond at the south end of the site to reduce post-development flows to near pre-development conditions. The rationale for the pond is discussed in Section 7.1.1.3. Alternative means of conveying site runoff to the Welland River are assessed in Section 7.1.1.2.

The landfill surface drainage concept is sufficiently flexible to accommodate other site development requirements.

CHAPTER 5
METHODOLOGY

5.1 HYDROLOGY

5.1.1 GENERAL

This Chapter summarizes the study approaches and methods employed for the prediction of surface water impacts resulting from construction and operation of the OWMC facilities. This includes methods for estimating post-develoment flows and runoff volumes from the site, together with associated impacts on off-site watercourses. The estimation of site susceptibility to flooding from off-site watercourses has been considered along with impacts on local surface water use. Methods are also outlined for estimating the erosion potential of various construction activities and land uses. The effect of OWMC water taking from the Welland River has been considered, together with the approach for dealing with accidental releases of contaminants from the site into the surface drainage system and the receiving waters.

5.1.2 FACTORS AND INDICATORS

At the beginning of Phase 4B, surface water factors were identified to provide a basis for the evaluation of impacts resulting from construction and operation of the facility. Factors relating to the surface water environment were reduced to two: water quantity and water quality. These factors reflect the overall OWMC goals of minimizing risk, impact and cost associated with the proposed development.

For each factor, several indicators (or components of the factor) were identified to focus the impact analysis. The factors and indicators adopted for the surface water assessment are listed in Table 5.1.

TABLE 5.1
PHASE 4B FACTORS AND INDICATORS - SITE ASSESSMENT

Factor	Indicator
1. Water Quantity	° Peak flows and volumes (site) ° Susceptibility to site flooding from off-site watercourses ° Water use
2. Water Quality	° Erosion and sedimentation ° Water taking (Welland River) ° Accidental release of contaminants to surface waters

Table 5.2 provides a definition of the surface water factors together with their rationale/significance. A detailed discussion of the factors and indicators is included in Chapters 5 (this chapter), 6 and 7.

TABLE 5.2

PHASE 4B SURFACE WATER FACTORS

FACTOR	DEFINITION	RATIONALE/SIGNIFICANCE
o Surface Water Quantity	- The quantity of surface water may be altered by development of OWMC facilities. This factor relates to changes in streamflow characteristic affecting runoff volume and duration and/or the magnitude of peak flows.	- The increase/decrease in peak flows and flood levels affects areas flooded, water velocities and potential for erosion. The diversion of water to or away from a local water course may also affect the duration and magnitude of the active streamflow period with resulting increase/decrease in supply for downstream water users.
o Surface Water Quality	- The quality of local surface waters may be impacted by development of OWMC facilities. Quality in this context relates to both physical and chemical properties of the water which may affect potential receptors/uses. Quality parameters include general chemistry (e.g., temperature, pH), nutrients (e.g., ammonia, phosphorous) bacteriological, trace constituents (e.g., arsenic, iron), and priority pollutants (e.g., organics, pesticides). Water quality criteria are defined as concentration limits or ranges within which the impact on the receptor is considered acceptable.	- Water quality may be impacted by release of contaminants to surface water and/or by surface withdrawals. Broad receptor categories include: - ambient water quality - drinking water - aquatic habitat - agricultural - recreational and aesthetic Health effects are possible through direct potable use, dermal contact, or indirectly through the food chain (plant or animal). Aquatic habitat receptors include fish and all waterborn organisms. Agricultural criteria generally govern the use of water for livestock watering or irrigation purposes. Aesthetic effects include siltation, visual impacts (e.g., algal bloom from nutrient enriched discharge) and possibly odour.

5.2 WATER QUANTITY

5.2.1 PEAK FLOWS AND VOLUMES (SITE)

Site development by OWMC will result in improved efficiency of drainage on-site and elimination of existing depression storage. Significent increases in peak flows can be expected, along with higher volumes of storm runoff, for given rainfall events. Potential off-site impacts include increased flows in downstream watercourses and flooding of adjacent lands, together with increased flow velocities and the associated erosion potential.

Methods used for the prediction of post-development flows and runoff volumes are described in the following sub-sections.

5.2.1.1 Hydrology

The OTTHYMO hydrologic model has been used to estimate the post-development flows. The same model was used to estimate the pre-development flows (Section 2.5.2 and Appendix D).

The model was used to generate runoff hydrographs from a range of design storms (5 year to 100 year return period). Results of the model have also been used to assess the effectiveness of various runoff control measures for reducing peak flows from the site and for determining the effect of landfill development on downstream areas. Details of this model are described in Part 1 of this volume and are not repeated here.

5.2.1.2 Input Parameters

The improved drainage system associated with the landfill development, described in Section 4.4, will increase both the runoff volume and peak flows discharging from the site. The input parameters required to model these increases are described below.

Design Storm Selection

To ensure a consistent comparison between existing and post-development flows, the same design storm data, distribution and return periods were used in both cases. This design storm data is summarized below.

i) Rainfall Gauge - Atmospheric Environment Service (AES) Vineland Station
ii) Distribution - Keifer and Chu
iii) Duration - 24 hours
iv) Discretization Interval - 10 minutes
v) Return Periods - 1:5, 1:10, 1:50, 1:100 year (for flow calculations)
vi) Return Period (for design) - 1:100 year.

Drainage Areas

As shown on Figure 4.2, the site was divided into three major sub-watersheds for post-development flow calculations. Each of these sub-watersheds represents runoff from separate and distinct proposed landfilling areas. Sub-watershed 1 includes the western portion of the site while Sub-watersheds 2 and 3 include the northeast and southeast portions of the site respectively. The size of the sub-watersheds depends on the time frame for which flows are being calculated. During the operational phase, the COA does not contribute to peak flows and hence this area is excluded

from the modelling exercise. After the facility has been decommissioned, it has been assumed that the entire site area will contribute runoff to the outlet. Accordingly, each of the three sub-watersheds has been increased in size to account for the additional runoff contribution from this area (see Table 5.3). These additional areas have been identified as 1A, 2A and 3A on Figure 4.2.

To ensure consistency in total drainage areas between existing and post-development conditions, two external areas (Sub-watersheds 4 and 5 on Figure 4.2) have also been included in the post-development conditions model. Runoff from these areas will be diverted around the site (outside of the perimeter berm) to existing outlets. They are only included so that a composite post- development hydrograph can be developed for direct comparison with the existing conditions composite hydrograph. The actual area of the site is 124 ha, compared to the total area modelled for the composite hydrograph, which exceeds 134 ha.

In summary, post-development flows have been modelled using five sub-watershed areas (three on-site and two external areas). All on-site sub-watersheds will contribute runoff to one outlet at the south end of the site. Runoff from the two external areas will be routed around the perimeter of the site and will discharge to existing outlets. The hydraulic assessment of the single outlet from the site will be based on runoff from the three on-site sub- watersheds, while downstream impacts will be based on the runoff volumes and peak flows from all five sub-watershed areas. Hydrographs have been computed for the operational phase of the development (no runoff peak contribution from COA) and for the post-operational period when the entire site is assumed to contribute runoff to the outlet (see Section 6.1).

Curve Number (CN)

The rationale for the selection of a curve number value of 79 for existing condition flow estimates is fully documented in Appendix D . In general, CN selection is based on soil type, land use and antecedent moisture condition as described previously. Since none of these parameters is expected to change from existing to post-development conditions, the same CN=79 value has been used.

Time to Peak

For existing conditions, times of concentration for the various sub-watersheds were generated on the basis of the Upland Method (U.S. Soil Conservation Service, 1985). For post-development conditions, the Upland Method has again been used in conjunction with stream hydraulics to account for the improved drainage system (well defined overland flow paths, intermediate swales and perimeter ditches). In general, overland flow lengths, intermediate swale lengths and perimeter ditch lengths were first estimated for each sub-watershed area. Overland flow times were then estimated using the Upland Method "overland flow (pasture)" and "grassed waterway" curves. Travel times through perimeter ditches were estimated using a slope of 0.1%, a one metre bottom width and 3:1 side slope cross-section and an assumed average velocity of 0.5 m/s. (This velocity is based on an anticipated range of flows from 1 to 1.5 m^3/s in the perimeter ditches.) Times to peak were then generated on the basis of the equation:

$$Tp = .6Tc + D/2$$

This equation is described in Appendix D. Tp estimates are summarized in Table 5.3.

Initial Abstraction

Under existing conditions, there are numerous low-lying, depression areas on the site which are poorly drained. The impact of these areas on the existing condition hydrographs was modelled using a relatively high value for initial abstraction (15 mm). However, with the improved drainage system proposed for the site, a positive gradient will be provided to the outlet and all of these poorly drained depression areas will be eliminated. Therefore, a more representative Initial Abstraction value of 2.5 mm has been selected for post-development conditions.

All model input parameters described above are summarized in Table 5.3 below.

TABLE 5.3
POST-DEVELOPMENT SUB-WATERSHED PARAMETERS

Sub-Watershed Number	Area (ha) During Operation	Area (ha) Post-Operation	Runoff Curve No.	Time to Peak (Hours)	Initial Abstraction (mm)
1	48.94	58.44	79	0.62	2.5
2	35.27	41.64	79	0.50	2.5
3	19.73	26.43	79	0.38	2.5
4	4.13	4.13	79	0.23	15
5	4.13	4.13	79	0.23	15

5.2.1.3 Hydrograph Routing

Under existing conditions, hydrograph routing through storage created by limited capacity outlet culverts, has the effect of significantly reducing peak flows from the site. However, the

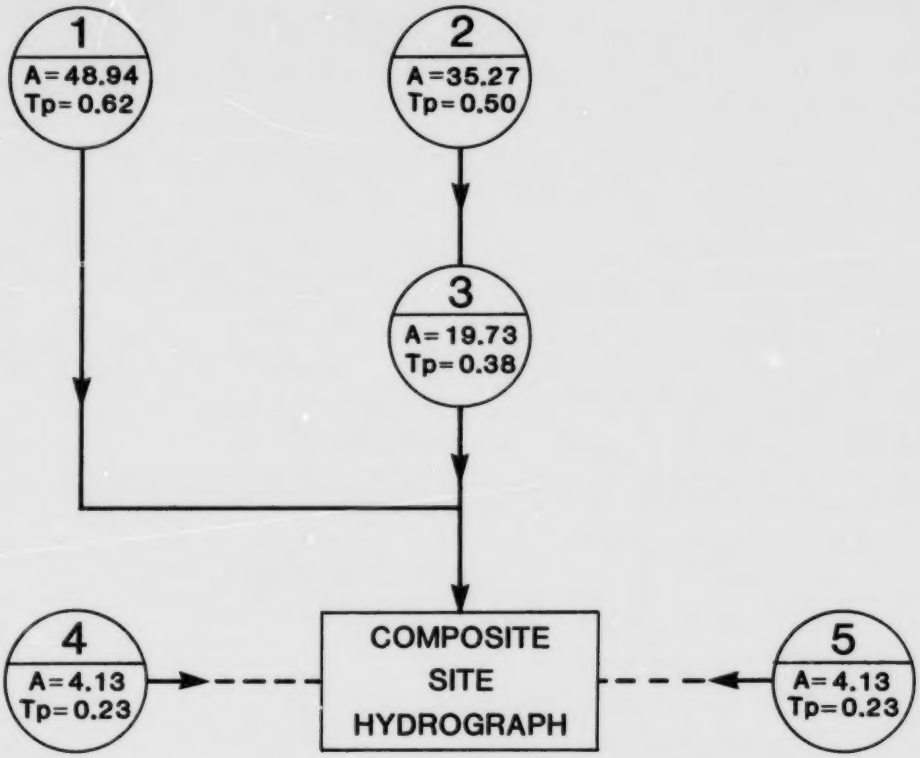
proposed improved drainage system will result in the elimination of this on-site storage and this moderating effect on flows will be lost. Accordingly, no storage routing is included in the calculation of post-development flows.

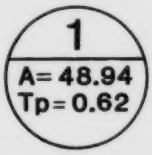
In summary, the improved grading (2% overland slopes), dense network of continuous drainage swales and perimeter ditches, and the elimination of outlet restrictions have all been accounted for in the input parameters described above. Each of these changes will act to increase peak flows and volumes discharging off-site. The OTTHYMO watershed model which was used to assess the magnitude of these peak flow and volume increases is described in Section 5.2.1.4.

5.2.1.4 Hydrologic Model

A schematic of the post-development OTTHYMO model is shown in Figure 5.1. This model was used to estimate maximum uncontrolled site and external area runoff expected during the operational phase of the facility. The only changes required to model post-operation conditions runoff are increases in the areas of Subwatersheds 1, 2 and 3 as described at the bottom of Figure 5.1.

The composite site hydrograph referred to on this figure represents the addition of all hydrographs generated on site (Subwatersheds 1, 2 and 3) and all external area hydrographs which would naturally drain through the site including Subwatersheds 4 and 5. This allows a direct comparison of the pre and post-development flow hydrographs and is helpful when examining the downstream impacts of the development.





Computed Hydrograph For Subwatershed #1
A- Drainage Area (ha)
Tp- Time to Peak (h)

NOTES 1) Area values shown are for "during operation" conditions.
2) Area values for "post operation" conditions are 58.44 ha, 41.64 ha and 26.43 ha for subwatersheds 1,2 and 3 respectively.

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SCHEMATIC OF POST-DEVELOPMENT CONDITIONS MODEL (No Controls)

FIGURE 5.1

5.2.2 SUSCEPTIBILITY TO SITE FLOODING FROM OFF SITE WATERCOURSES

Flooding of the Preferred Site from external watercourses (e.g. Sucker Creek would be of significant concern. Serious flooding could interupt site operations and potentially result in contamination of surface runoff. An investigation of the site flood potential from off-site watercourses was undertaken as part of the baseline studies (Part 1 of this report). Sucker Creek is the only watercourse in the site vicinity which could potentially flood the site under extreme events.

The methodology for conducting this hydrologic/hydraulic assessment of Sucker Creek is outlined in Section 2.5.3 and is not repeated here.

5.2.3 SURFACE WATER USE

The results of the baseline studies of surface water use on-site and in the site vicinity are summarized in Section 3.5. Local surface watercourses downstream of the site are used only for seasonal watering of livestock. No households in the study area are known to use surface streams as a source of drinking water or for non-potable domestic use.

Proposed surface water management features for conveyance of site runoff to the Welland River (as outlined in Chapter 7), will result in diversion of site drainage away from local watercourses immediately downstream of the site (9C Creek and Beaver Creek). This will result in a decrease in surface water supply to some downstream users by reducing the magnitude and duration of the active period. This will be most pronounced on 9C Creek, because of the size of the upstream area (70% of the Preferred Site area) diverted away from the local watercourse.

Given the intermittent nature of this resource and the limited use of same, the effect on surface water use associated with diversion of surface water is dealt with only briefly in Chapter 6.

5.3 WATER QUALITY

5.3.1 QUANTIFICATION OF EROSION

5.3.1.1 General

Erosion and subsequent sediment deposition in downstream areas, together with the associated degradation of surface water quality, frequently result from construction sites where bare soils are subject to the effects of wind and water. Similar effects may result from agricultural practices which expose soils to the elements over extended periods of time.

In general, erosion and sediment deposition will occur naturally over extended periods of time, but can be greatly accelerated by man's activities. Due to the complex nature of the erosion process and the number of variables involved, accurate quantification of soil loss is difficult. Although numerous mathematical models and solutions have been proposed, the results are necessarily coarse estimates, and tend to be site specific.

Numerous studies have been carried out to identify the variables which have the greatest effect on erosion and soil loss.

These include:

i) rainfall variables
ii) slopes and length parameters
iii) susceptibility of various soil types to erosion
iv) plant cover and mulches
v) cropping practices and tillage.

The Universal Soil Loss Equation (USLE) was developed in an attempt to predict average annual soil loss by using only the significant variables affecting erosion.

5.3.1.2 Universal Soil Loss Equation (USLE)

The USLE is a statistical regression model based upon soil loss data obtained from test plots in the U.S.A. The equation was designed to quantitatively predict sheet and rill erosion from fields and construction sites (MTC, 1985). It takes the form:

$$E = 2.24\ RK(LS)(VM)$$

This equation expresses the annual soil loss per unit area (E) as the product of factors for rainfall (R), soil erodibility (K), overland length and slope (LS) and erosion control factor (VM).

Whereas the R, K and LS factors determine basic soil erosion potential of a given site, the VM factor represents local artificial effects due to management and conservation practices and may be viewed as a modifier of the basic R, K and LS factors.

A description of the various factors follows:

Rainfall Factor (R)

Detaching and transporting soil material requires energy, the majority of which is supplied by falling raindrops and surface runoff. The rainfall factor R, is a measure of such energy and has an average value depending upon the rainfall intensity-duration-frequency characteristics of the location. The R value for the Preferred Site has been established as approximately 100 from the iso-erodent map shown on Figure 5.2. This map has been reproduced from the Ministry of Transportation and Communications Drainage Manual (MTC, 1985).

Soil Erodibility

This factor is a measure of the susceptibility of soil to erosion. It accounts for the combined effects of the soil's water intake and its ability to resist detachment by raindrop impact or surface runoff. The factor, therefore depends upon the local soil characteristics and requires knowledge of the soil particle, size distribution, organic matter content, structure and permeability. Based on the clay loams which exist in the area, a K factor of 0.3 has been estimated for the Preferred Site (MTC, 1985).

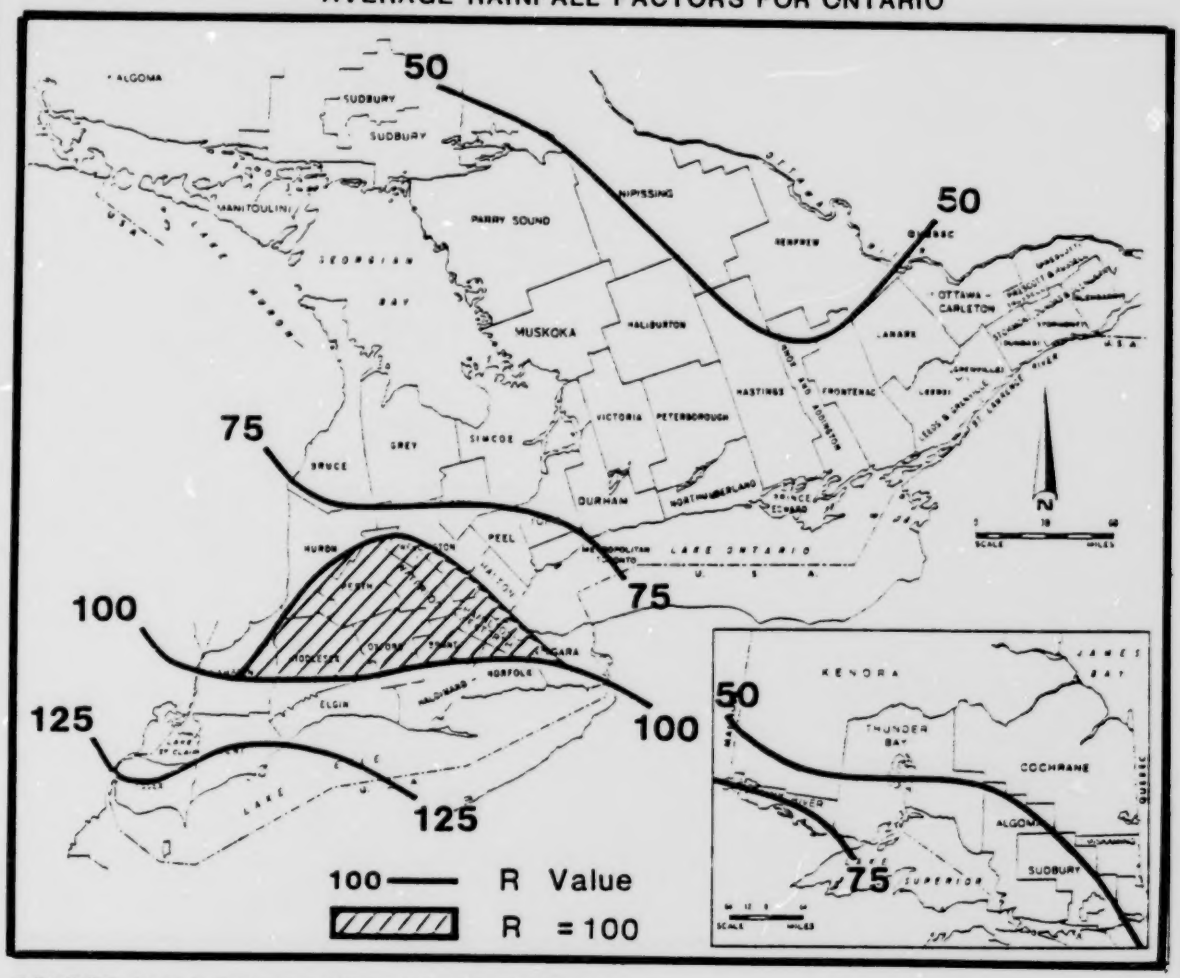
Topographic Factors (LS)

Erosion is highly dependent upon land gradient (which affects runoff velocity) and flow path length (which affects runoff volume). The topographic factor LS represents the combined effect of these two physiographic parameters. LS values for various slopes and lengths are shown on Figure 5.3.

Erosion Control Factor (VM)

The erosion control factor (also referred to as the cover or vegetative factor) characterizes the effects of vegetative and non-vegetative methods of controlling erosion. It does not include the effects of straw bale dykes, ditch check dams, sediment basins, etc. since the USLE cannot quantify the effect of these measures.

AVERAGE RAINFALL FACTORS FOR ONTARIO



SOURCE: M T C Drainage Manual, Volume 2,1985

NOTE: R Values Include An Allowance For Snowmelt

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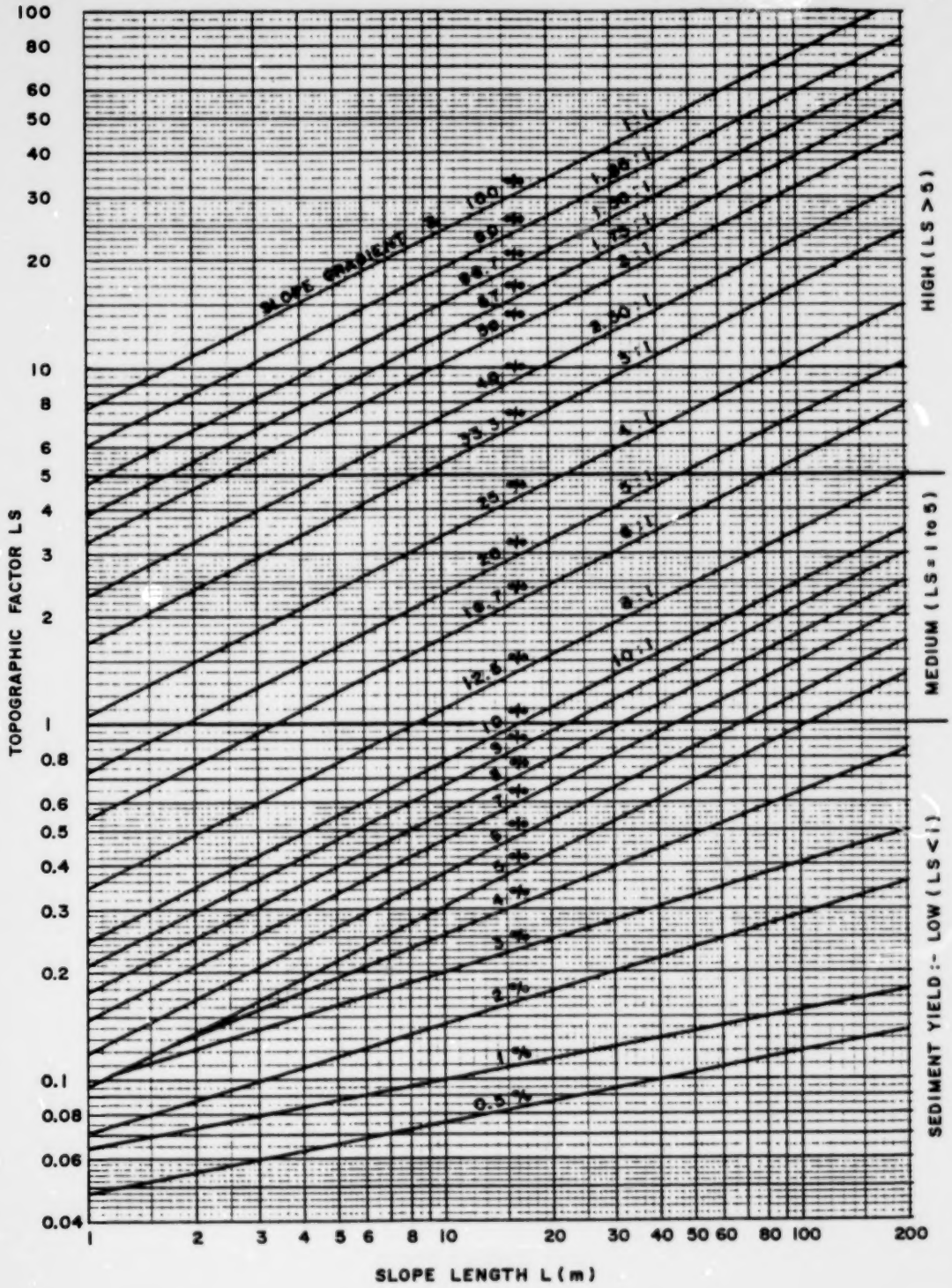
UNIVERSAL SOIL LOSS EQUATION
AVERAGE RAINFALL FACTORS (R)

FIGURE 5.2



SOURCE: M T C Drainage Manual, Volume 2, 1985

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UNIVERSAL SOIL LOSS EQUATION TOPOGRAPHIC FACTOR (LS) BASED ON SLOPE LENGTH AND GRADIENT

FIGURE 5.3

Unprotected bare soil has a VM factor of 1.0 while the VM factor for an area of well established grass is 0.01. Typical VM factors for various cover conditions are summarized in Table 5.4.

In summary, the USLE has been employed in this study as a tool to:

a) identify the potential for soil loss which could occur if bare soils were left unattended;

b) compare the effects of alternate land uses, representing existing, interim and future conditions.

It should be noted that the predicted erosion rates provide only a coarse estimate of actual rates of erosion. However, they do provide an indication of the magnitude of the problem for various construction activities/land uses, as well as the level of control anticipated with various mitigative measures.

5.3.2 WATER TAKING - WELLAND RIVER

Proposed water taking from the Welland River by OWMC for process water and potable use has been examined in relation to existing streamflow and water levels in the Welland River and in the context of Ontario Hydro operations downstream. No detailed quantitative analysis is warranted in light of the negligible impacts associated with the OWMC water taking, as discussed in Section 6.2.2.

5.3.3 WATER QUALITY

The results of the water quality baseline studies are documented in Part 1 of this report. Water quality impacts are briefly considered in Chapter 6.

TABLE 5.4
UNIVERSAL SOIL LOSS EQUATION

TYPICAL EROSION CONTROL FACTORS (VM)
(Source: MTC Drainage Manual, Volume 2, 1985)

Description	Average VM Value
1. Bare soil	1.00
2. Grass	
a) Seeded - up to 60 days	0.40
- 60 days to 12 months	0.05
- after 12 months	0.01
b) Sodded	0.01
c) Grass and weeds	0.01
3. Mulch	
a) Straw (2 tonnes/ha)	0.01
b) Wood chips (11 tonnes/ha)	0.01
c) Crushed stone (100 tonnes/ha)	0.01
d) Excelsior blanket (plastic net)	0.07
Emulsified asphalt (on bare soil)	0.68
4. Miscellaneous	
a) Brush	0.02
b) Forest	0.002

Note: If seed and mulch are applied, use the lower value of the two.

Under normal operating conditions, the OWMC facility is predicted to have negligible impact on local surface water resources and in particular on the principal receiving watercourse, the Welland River. This is by virtue of a number of key facility design and surface drainage management features proposed.

The potential for surface water contamination as a result of facility upset conditions and/or accidents is being addressed by the hazards and operability analysis (Battelle, 1987). This study has addressed the probability of accidental discharge of contaminants or contaminated storm water into the Welland River via the surface drainage system. The risk of accidental release of contaminated runoff from the site is very low (Battelle, 1987). Appropriate control measures are proposed as part of OWMC's emergency response plan.

Water quality impacts associated with the incinerator stack emissions have been undertaken for OWMC by Environ (1987) in the ecorisk analysis including the potential contamination of ponds, cisterns and surface streams. Environ has also evaluated the risks associated with transportation spills into surface water (Environ, 1987).

CHAPTER 6
PREDICTED IMPACTS

6.1 WATER QUANTITY

6.1.1 PEAK FLOWS AND VOLUMES

6.1.1.1 Post-Development Flows - Site

The results of the post-development flow modelling for the Preferred Site are summarized in Table 6.1. This table presents flow estimates for two cases:

i) during facility operation when all runoff within the COA is retained and tested prior to release;

ii) after facility closure (post-operation) when the COA facilities are removed from the site and the area is regraded and revegetated similar to the surrounding landfill area.

TABLE 6.1
SUMMARY OF POST-DEVELOPMENT FLOW ESTIMATES

Subwatershed No. (Refer to Figure 4.2)	Area (hectares)		1:100 Year Flow (m^3/s)	
	During Operation	Post-Operation	During Operation	Post-Operation
1	48.94	58.44	4.29	5.13
2	35.27	41.64	3.60	4.25
3	19.73	26.43	2.46	3.29
2+3	55.00	68.07	4.74	6.00
1+2+3	103.94	126.51	9.04	11.15
4	4.13	4.13	0.44	0.44
1+2+3+4	108.07	130.64	9.40	11.50
5	4.13	4.13	0.38	0.38
1+2+3+4+5	112.20	134.77	9.75	11.84

Notes: i) Subwatershed Nos. 1, 2 and 3 represent runoff from the site area (to the south end of the site).

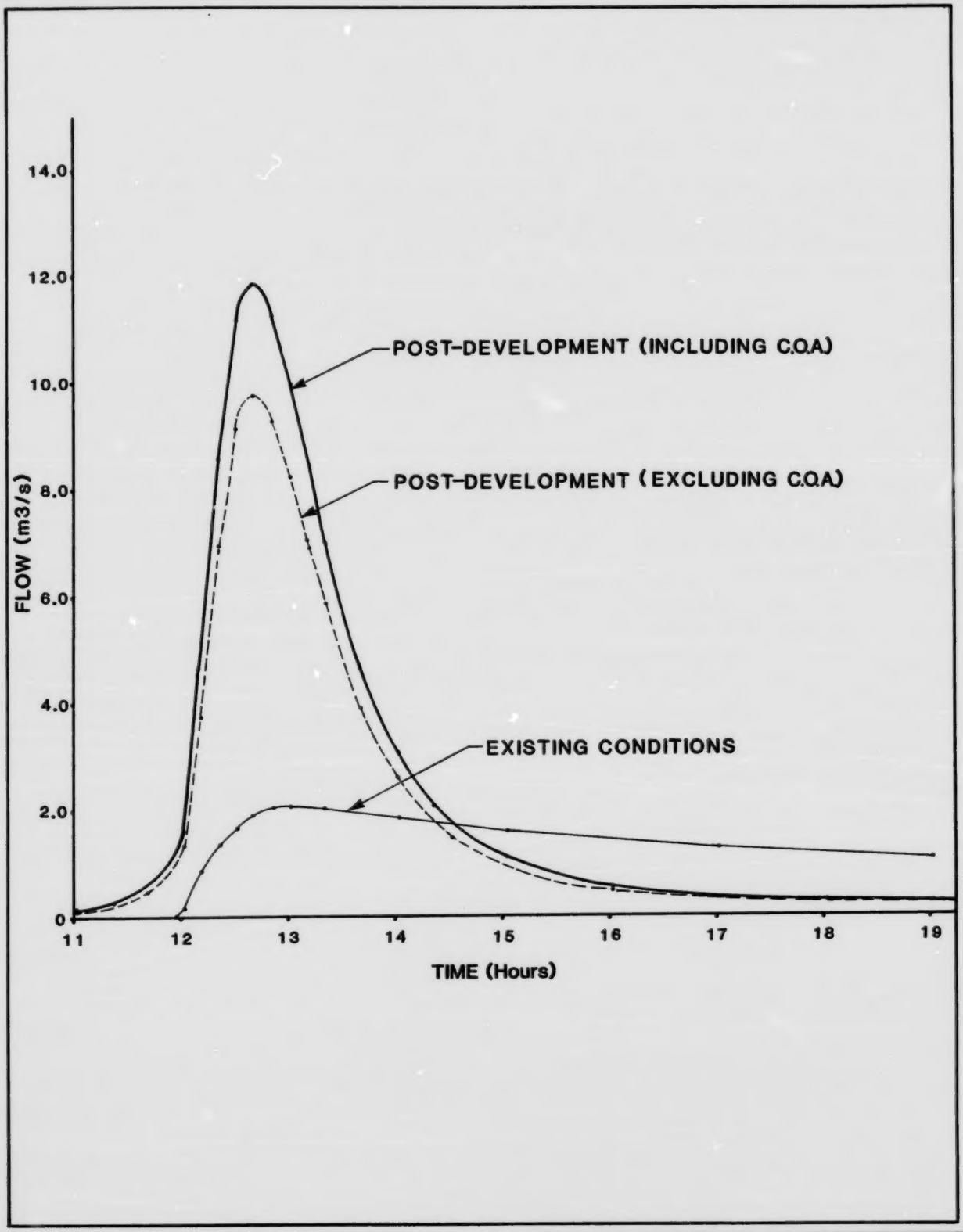
ii) All subwatersheds combined represent the composite hydrograph (including external areas).

Flows are lower for case i) above because the COA will not contribute to peak flows from the landfill area. All runoff from the COA will be retained and tested on-site prior to release (by pumping) downstream at a low rate. For this case, the area contributing to runoff is estimated to be 112.2 ha. By comparison, the area contributing to runoff when the COA facilities are removed is 124 ha (or approximately 135 ha with external areas included (refer to Section 5.2.1.2). Under worst case conditions (post- closure), the 1:100 year flow is estimated to be 11.84 m^3/s. This compares to the existing conditions (no development) flow estimate of 2.06 m^3/s. These comparisons are valid for the entire site area plus the two small external drainage areas.

The impact of development on existing condition flows is substantial as shown on Figure 6.1. It is estimated that under post-development conditions peak flows could increase by up to six times. This results from the elimination of natural, low lying swampy areas, elimination of limited capacity outlet culverts and the construction of a network of intermediate swales and perimeter ditches, through and around the site.

6.1.1.2 Peak Flows and Runoff Volumes - Local Watercourses

Without mitigation, the estimated six-fold increase in peak flows between existing and post-development conditions would have a major impact on downstream watercourses. Specifically, peak flow increases would occur along the Beaver Creek tributaries, along 9C Creek and to a lesser extent along Sucker Creek. These peak flow increases would result in increased flooding through several downstream private properties. Flow increases from the site would also increase the potential for erosion along some of the local intermittent watercourses. Existing erosion has been identified along 9C Creek south of the site.



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IMPACT ASSESSMENT
1:100 YEAR HYDROGRAPHS

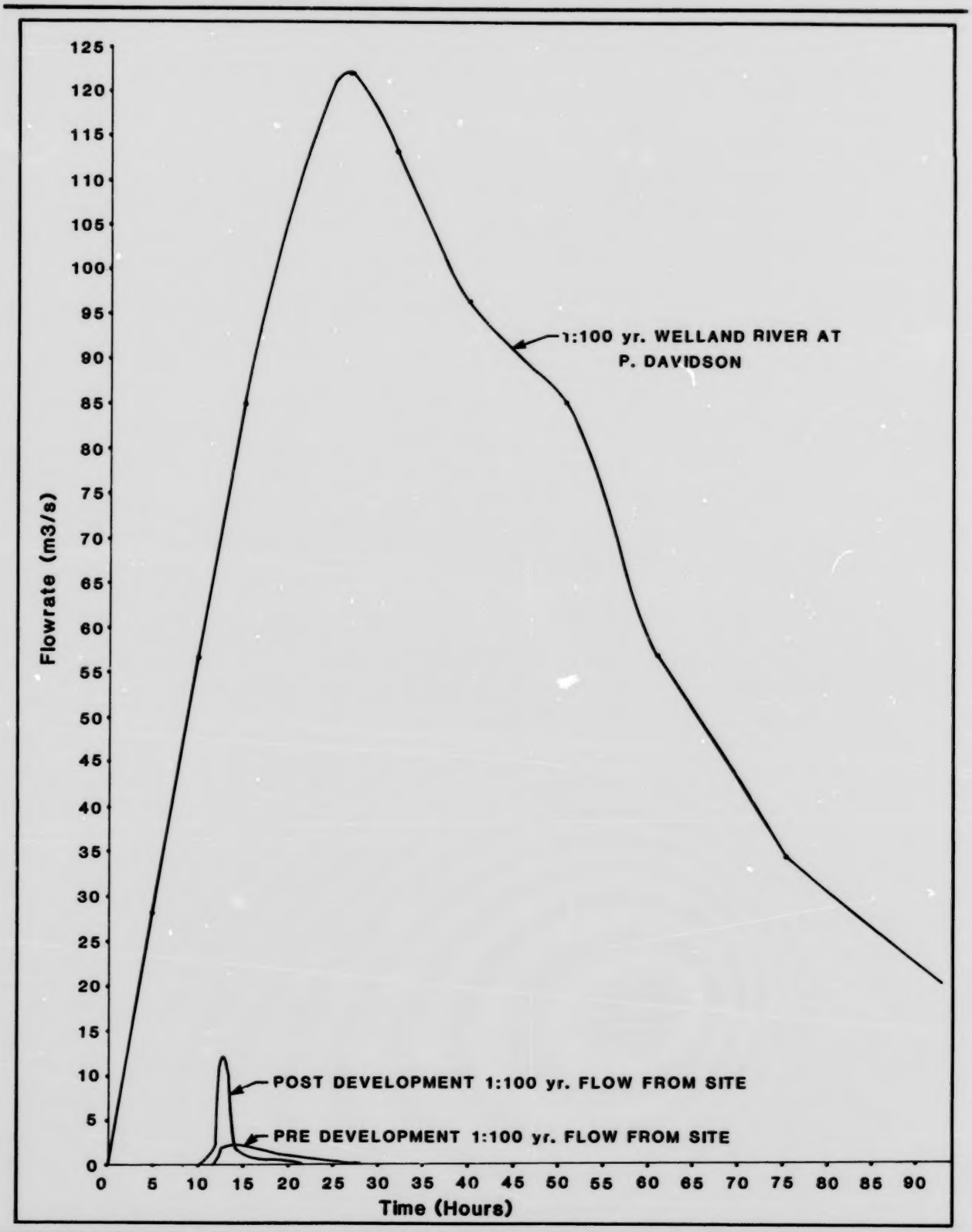
FIGURE 6.1

6.1.1.3 Peak Flows and Runoff Volumes - Welland River

The Beaver Creek tributaries, 9C Creek and Sucker Creek all drain to the Welland River, approximately 2-3 km south of the site. The intermittent nature of these creeks, combined with their relatively small drainage areas and poorly defined cross-section, will likely result in flooding and/or erosion problems if development is allowed to proceed upstream without mitigation measures.

However, the Welland River, with its relatively large upstream drainage area (548 km^2) compared to the site drainage area (1.24 km^2) will not be significantly affected by increased runoff (peak flows and volumes) from the site. This is illustrated on Figure 6.2. The very large hydrograph on this figure represents the 1:100 year runoff event from the Welland River watershed upstream from the location where site runoff would discharge to the river (Dillon, 1985). The other two hydrographs represent pre- and post-development runoff conditions from the site alone. These hydrographs indicate that although the relative flow increase from the site may be substantial (i.e. from 2 m^3/s to 12 m^3/s), the impact on the Welland River is not significant because of the much larger contribution of runoff volume from upstream. Also, the relatively short distance from the site to the river (2 km) compared to Welland River watershed length (40 km) (from the headwaters to the site discharge location) will result in little, if any, addition to peak flows on the Welland River.

The impact that increased runoff volume from the site will have on the Welland River can also be viewed in terms of increase in depth of flow. Under post-development flow conditions, it is estimated the site runoff volume will increase by approximately 21% over existing conditions. This represents an additional volume of 1.3 hectare-metres (ha-m) discharged to the Welland



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COMPARISON OF SITE AND WELLAND RIVER 1:100 YEAR HYDROGRAPHS

FIGURE 6.2

River. Assuming a flow velocity of 0.5 m/s and a duration of discharge of approximately 4 hours, yields a travel distance downstream of 7200 m. Since 150 m is typical of the channel top width through this reach, the area over which this additional volume may spread is approximately 108 ha. Therefore, the increase in volume discharging to the Welland River as a result of developing the site area is estimated to be 0.012 m (0.5 in.). This increase is considered insignificant in terms of impact on the Welland River.

6.1.2 SUSCEPTIBILITY TO SITE FLOODING FROM OFF-SITE WATERCOURSES

The potential for Sucker Creek to flood the site under extreme events was examined and is discussed in Part 1 of this report (Section 3.4). The results of the analysis indicated that back-up of floodwaters onto the site from Sucker Creek may occur for the Regional Storm (Hurricane Hazel), if it was centred over the watershed. This could occur via two culverts under Highway 20, west of Silverdale Road.

While the impact on flows through the site would not be significant, this situation would not be desirable when the OWMC facility is operating. The opportunity for flood waters from Sucker Creek to access the site will be eliminated in design by proposed ditching and berming around the perimeter of the site.

6.1.3 SURFACE WATER USE

9C Creek presently drains approximately 70% of the site area through downstream lands. The water use survey indicated that 9C Creek is used by three landowners downstream from the site for seasonal livestock watering. Therefore, diversion of all site runoff from 9C Creek to the proposed Heaslip Road storm sewer (as discussed in Chapter 7) may impact upon this water use.

A comparison of drainage areas contributing runoff to 9C Creek before and after the proposed diversion is presented in Table 6.2.

TABLE 6.2
9C CREEK DRAINAGE AREA REDUCTION RESULTING FROM DIVERSION OF SITE DRAINAGE TO PROPOSED HEASLIP ROAD STORM SEWER

Location	Existing Drainage Area (ha)	Drainage Area After Diversion (ha)	% Decrease
Vaughan Road	92.6	0	100
Elcho Road	201.6	109	46
Welland River	232.6	140	40

A review of the data presented in Table 6.2 indicates that the reduction in area contributing runoff to 9C Creek is substantial, varying from 100% at Vaughan Road to 40% at the Welland River. If runoff volume can be related directly to drainage area then the same percentage reductions apply.

Given the intermittent nature of 9C Creek, use of surface water would be limited to periods of significant precipitation and surface runoff. This creek could not be counted on for a secure source of water for livestock. Nevertheless, diversion of site runoff away from 9C Creek will reduce the availability of supply for stock watering on three properties.

Conversely, diversion may have a positive effect on downstream flooding. The water use survey identified two properties along 9C Creek where flooding has been a problem in the past. Where these flooded areas are remote from 9C Creek and result from

localized depressions and a poorly defined overland flow path, then the diversion will have no effect. However, where flooding results from high flows in the creek, then the diversion will have a beneficial effect on the flooding problem. A reduction in contributing area will reduce peak flows and volumes downstream and will therefore result in a decrease in frequency and magnitude of downstream flooding.

The two property owners potentially benefiting from reduced flooding, are also those affected by loss/reduction in the use of surface water for stock watering.

6.2 WATER QUALITY

6.2.1 EROSION AND SEDIMENTATION

6.2.1.1 Potential Erosion From Construction Activities

The Universal Soil Loss Equation described in Section 5.3.1 was used to estimate the rates of erosion which could be expected from the various landfill areas under existing, interim and future conditions.

The landfill areas referred to above include the undisturbed areas, areas stripped of topsoil, berms, ditches, stockpiles and the completed landform.

For all calculations, the Rainfall Factor (R) and the Soil Erodibility Factor (K) have been held constant at 100 and 0.3 respectively. Differences in erosion rates from the various landfill areas and time periods have been accounted for by varying the Topographic Factor (LS) and the Erosion Control Factor (VM).

With R and K held constant the USLE becomes:

$$E = 67.2\ (LS)(VM)$$

Under existing conditions, the entire site is covered with crops, grass, brush and trees. From Table 5.4, a VM value of 0.01 is representative of a fully vegetated site. Also from the existing site cross-sections shown in Figure 4.1, overland flow slopes of 2% and representative lengths of 60 m have been selected for calculation of the LS factor. From Figure 5.3, a 2% slope and 60 m overland flow length results in an LS factor of 0.25. Therefore, the estimated soil loss from the existing undisturbed site is approximately 0.2 tonnes/hectare (t/ha).

Under interim conditions, erosion may occur from several different areas, depending on the approximate slope and length of the area being examined. Initially, topsoil will be stripped from a portion of the existing site area in preparation for landfilling, the perimeter berms and ditches will be constructed and topsoil and fill stockpiles will be created. All of these activities will result in bare soils being exposed to the elements for varying periods of time. As a result, the potential for erosion to occur from these areas is much greater than under existing, fully vegetated conditions.

To quantify this increase, the LS and VM factors in the USLE have been adjusted. For portions of the site which have been stripped of vegetation and topsoil, the overland slopes (up to 2%) and lengths (60 m) will remain the same as existing, resulting in an LS factor of 0.25 (same as existing). However, from Table 5.4, the VM factor for bare soils increases to 1.0 (compared to .01 under existing conditions). The result is an estimated soil loss of about 20 t/ha from areas where vegetation and topsoil have been stripped from the site. A similar rate of soil loss

would be expected from agricultural land of similar characteristics during periods of cultivation when soils are bare (e.g. ploughing, planting).

Similarly, unvegetated berms, ditches and stockpiles will have overland slopes ranging from 33% to 50% and lengths ranging from 2 to 16 m. The resulting LS factor ranges from 4.6 to 13.0, yielding a range of annual soil loss rates from 300 to 900 t/ha.

As landfilling proceeds and final cover is applied, the site topography will be restored as near as possible to existing conditions (2% slopes, 60 m lengths). Therefore, from the time that final cover is applied until a vegetative cover is achieved, erosion will occur at a rate equivalent to that which would occur when vegetation and topsoil is initially stripped from the site (20 t/ha).

The very high potential soil loss rate from the berms, ditches and stockpiles under bare soil conditions suggests that the time period over which these surfaces are left unprotected should be minimized. If these areas are seeded and mulched immediately after construction, then the VM factor drops to 0.01, the equivalent of a fully grassed area. The loss rate drops from a range of 300 - 900 t/ha to the range 3 - 9 t/ha.

Once landfilling is completed and the entire landfill area is revegetated, the soil loss rate will drop back to a value similar to that presently occurring on the existing site (0.2 t/ha). This is because final cover will be placed to match existing topography as closely as possible.

The soil loss rates for existing, interim and future conditions as described above are summarized in Table 6.3.

TABLE 6.3
ESTIMATED SOIL LOSS RATES

Time Period	Erodible Area	Slope (%)	Length (m)	Topographic Factors (LS)	Erosion Control Factor (VM) Description	Erosion Control Factor (VM) Value	Approximate Annual Soil Loss (Tonnes/ha)
Existing	Entire Site	up to 2	60	0.25	grass, brush	0.01	0.2
Interim	a) Portion of site stripped of topsoil	up to 2	60	0.25	bare soil	1.0	20
	b) Unvegetated berms, ditches and stock-piles	33-50	2-16	4.6-13	bare soil	1.0	300-900
	c) Unvegetated completed landform	up to 2	60	0.25	bare soil	1.0	20
	d) Vegetated berms, ditches and stockpiles	33-50	2-16	4.6-13	grassed	0.01	3-9
Future	Vegetated completed landform	up to 2	60	0.25	grassed	0.01	0.2

Notes:

i) Loss estimates refer to that occurring as a result of sheet and rill erosion. There is no accounting for the amount of material which may be deposited prior to reaching the site outlet.

ii) Topographic Factor (LS) obtained from Figure 5.3.

iii) Erosion Control Factor (VM) obtained from Table 5.4.

iv) Loss estimates based on Universal Soil Loss Equation.

v) Final grading assumed similar to existing.

The potential for increased erosion will also exist during construction and restoration activities for the off-site facilities such as the raw water pumping station and the watermain and storm sewer on Heaslip Road.

Results in Table 6.3 indicate that because the existing site has very mild overland slopes and is fully vegetated, the potential for soil loss is very small (0.2 t/ha). Also, because final grading is going to be carried out to match existing slopes and the site will be fully revegetated, there will be little difference between soil loss rates for existing and post-closure conditions. However, during the construction and operational phases, there is potential for high soil loss rates. Accordingly, it is very important that bare soils be revegetated as quickly as possible and that other means of erosion and sediment control be considered. Alternate means of controlling erosion are discussed in Section 7.2.

6.2.1.2 Erosion and Sedimentation Impacts - Site and Site Vicinity

It has been shown in Section 6.2.1 that development of the Preferred Site will greatly accelerate the erosion and sediment deposition processes between the times of initial construction and final closure. The impacts associated with allowing site erosion to occur unchecked include:

i) loss of cover over completed portions of the landfill;
ii) frequent maintenance on-site;
iii) loss of capacity within internal and perimeter ditches;
iv) loss of capacity within immediate receivers (Sucker Creek, 9C Creek and Beaver Creek tributaries);
v) impaired water quality in downstream areas which may have an impact on downstream users and biological resources;

vi) reduced culvert capacity due to silting;
vii) increased flooding.

These impacts may occur on-site and in the immediate receivers, if erosion and sedimentation are allowed to occur unchecked throughout the landfill development period. Means of mitigating these impacts are discussed in Section 7.2.

6.2.1.3 Erosion and Sedimentation - Welland River

For purposes of this report, the Welland River is the ultimate receiver of sediment laden runoff from the Preferred Site. Undoubtedly, some sediment leaving the site would be deposited in downstream swales and channels prior to reaching the Welland River.

The actual quantities of sediment which would reach the Welland River in runoff from the Preferred Site, and the associated impacts, are difficult to assess. The Welland River watershed is comprised primarily of clay soils and is principally in agricultural land. The river's suspended sediment load is already substantial. Generally, suspended sediment loads in Ontario rivers range from about 0.2 up to in excess of 1.0 tonne/hectare/annum. This converts roughly to between 10 000 and 55 000 tonnes/annum for the 548 km^2 drainage area of the Welland River near the Preferred Site. A preliminary estimate of suspended sediment load in the Welland River (based on existing Ministry of Environment data and limited data collected for this study) lies within the range for typical suspended sediment load in Ontario rivers.

Given the existing sediment load in the Welland River, and its large upstream drainage area (548 km^2), compared with the limited site size (1.24 km^2), it is unlikely that sediment derived from the Preferred Site during the construction and operational phases will have a significant impact on water quality in the Welland River.

However, practical means of reducing site erosion and downstream sediment deposition are recommended in light of the potential significant local increase in sediment from exposed soils on-site during the construction and operational phase. Such measures will ensure that development of the site has minimal impact on the sediment load in the Welland River.

6.2.2 WATER TAKING - WELLAND RIVER

OWMC has selected the Welland River as the source of water for process requirements and for potable water. The normal rate for water taking is estimated at 145 tonnes/day (t/d) based on the 150 000 t/d treatment capacity (Monenco, 1986). This is equivalent to a withdrawal rate of approximately 22 imperial gallons per minute (IGPM) or 0.0017 m^3/s. The normal water demand could double if the treatment facilities are expanded to the 300 000 t/d scenario.

Under worst case conditions (i.e. when no recycled water is available from the physical/chemical treatment plant), the maximum water demand could reach 900 t/d, equivalent to a flow of approximately 138 Igpm or 0.01 m^3/s.

Based on Table 3.4, the annual minimum daily flow in the Welland River approaches zero or near zero regularly. On occasions these low flow periods are of considerable duration, particularly during summer periods with minimal precipitation.

Under a normal river regime, water takings by OWMC particularly at the low flow period, could be expected to reduce base flows, lower river water levels and possibly impair river water quality. However, as noted in Section 3.2.2.4 and shown on Figure 3.3, water levels at the proposed intake site are controlled by Ontario Hydro operations downstream and ensure adequate depth over the intake at all times. Even during periods of no flow in the Welland River, water withdrawn by OWMC will be continuously replenished from downstream. No measurable effect on water levels is expected in the Welland River as a result of the proposed water taking, even under worst case conditions. Similarly, water quality should not be adversely affected by OWMC water taking from the Welland River.

No mitigation measures are warranted.

6.2.3 ACCIDENTAL RELEASE TO SURFACE WATER

Based on the Phase 4B studies, virtually no adverse water quality impacts are predicted for the downstream watercourses under normal facility operations. This results from a number of important surface drainage management features to be incorporated into the design of the facilities (refer to Section 2.2.1).

The specific management features affecting surface water quality are:

- No discharge of process water to local watercourses.

- Segregation of surface drainage between the Central Operating Area (COA) and the landfill.

- Segregation of uncontaminated and potentially contaminated water both within the COA and on the landfill.

- Testing of all runoff from the COA prior to release.

- Testing of all potentially contaminated runoff from the landfill prior to release.

- Treatment of all runoff not meeting accepted quality criteria.

- Adoption of the shallow entombed landfill concept, thereby minimizing to risk of interconnection between contaminated ground water and the surface drainage system.

- Trucking of sanitary sewage off-site to existing treatment facilities.

The potential for surface water contamination as a result of facility upset conditions and/or accidents on-site is currently being addressed in the hazards and operability analysis (Battelle, 1987). The study has addressed the risk of accidental discharge of contaminated storm water from the COA to the Welland River. The probability of an unrecovered release of contaminated surface water to the environment has been estimated by Battelle as 0.00000205 per drainage opportunity (Battelle, 1987). Assuming a runoff event frequency of 90 times per year, the annual probability of such an event occurring is approximately 0.000185. This equates to a frequency of occurrence of once every 5400± years (or a probability of about 0.01 over an assumed 50 year site life).

Contingency measures to be implemented in the event of an accidental release of contaminated storm water are discussed in Chapter 7. These include notification of water users along the Welland River, provision of alternate water supplies on a temporary basis for those users affected and implementation of appropriate remedial measures for spill containment and clean-up.

6.3 SUMMARY

A concise summary of surface water impacts and their significance, together with impact management measures and options is provided in Table 6.4. The management options are discussed in Chapter 7.

We note that the surface water impacts identified in this report are equally applicable to the facilities based on either the 150 000 t/a or the 300 000 t/a treatment scenario. While the runoff volumes and peak flows within the COA are sensitive to the size of the impervious areas, the impact on off-site peak flows is mitigated by virtue of total retention of storm runoff from the COA for water quality testing.

TABLE 6.4

SURFACE WATER IMPACTS AND IMPACT MANAGEMENT MEASURES AND OPTIONS

IMPACTS	SIGNIFICANCE OF IMPACTS	IMPACT MANAGEMENT MEASURES AND OPTIONS
o under post development conditions, the peak flows and runoff volumes (for the 1:100 year storm) from the site will increase by almost six times (increased flows are the result of the elimination of on-site depression storage and increased efficiency of on-site drainage network); the comparable runoff volume is expected to increase by approximately 21%; anticipate increased flooding of agricultural land and increased erosion along intermittent creeks between the site and the Welland River	o significant increase in flood levels and erosion on agricultural lands along intermittent watercourses between site and Welland River; greatest impact along 9C Creek which currently drains approximately 70 percent of site. Existing local watercourses are poorly defined, with very limited conveyance capacity.	o routing of all site runoff to a common outlet at the south end of the site o channelization of 9C Creek or Sucker Creek or provision of storm sewer along Heaslip Road (preferred)
o increased runoff from the site would also increase flows and water levels in the Welland River by up to 0.012 m (0.5")	o no increase in peak flow in Welland River; potential for very minor increase in volume of floodplain storage. The impact on runoff peak and volume is not significant in the Welland River because the peak flow from the site is not coincident with the peak in the Welland River and because of much larger drainage area and flow/volume from the Welland River, upstream from the confluence with 9C Creek	o provide storm water management pond at south end of site to: - limit post-development flows to pre-development levels; - reduce size of conveyance system between site and the Welland River (e.g. Heaslip Road storm sewer)
o the diversion of surface water away from 9C Creek and other watercourses will result in a decrease in surface water supply to downstream users	o impact considered minor due to intermittent nature of watercourses involved and limited usage of 9C Creek for stock watering; offsetting benefit of diversion is potential reduction in existing flooding and erosion along 9C Creek	o replacement of supply via raw water line on Heaslip Road
o site flooding from external watercourses could interrupt site operations and potentially contaminate surface runoff	o minor back-up of flood waters from Sucker Creek is possible under extreme events (e.g. Regional Storm) via two culverts under Highway 20	o ditching and berming around perimeter of site will eliminate this potential problem
o erosion (on-site) from construction and operational activities resulting in soil loss and potential for downstream sedimentation and water quality impairment	o normal exposure of bare soils for limited periods for construction can be compared with typical agricultural operations involving certain cropping practices (e.g. ploughing, cultivating, planting, etc.). While baring of soils does increase the potential for erosion, it is not considered of great significance Bare soils associated with slopes (i.e. berms, stockpiles, ditches) exhibit higher erosion potential. However, given the length of ditches and perimeter berms involved with the OWMC facility, appropriate mitigation measures are proposed	o erosion control at source: - minimize area and time of exposure of bare soils; - revegetate disturbed areas as quickly as possible; - provide sediment barriers as appropriate around berms and stockpiles prior to establishment of vegetative cover; - provide non-vegetative cover as a temporary measure when seasonal timing precludes development of vegetative cover; - slope modification to reduce erosion potential; - maintain vegetation buffer strips where appropriate

TABLE 6.4
SURFACE WATER IMPACTS AND IMPACT MANAGEMENT MEASURES AND OPTIONS
(continued)

IMPACTS	SIGNIFICANCE OF IMPACTS	IMPACT MANAGEMENT MEASURES AND OPTIONS
		o other measures: - check dams/traps in perimeter ditches with periodic cleaning; - modification of storm water pond outlet to serve dual purpose of storm water and sediment control during construction period (contingency only)
o water taking from the Welland River will result in potential reduction in river flow and associated deterioration in water quality particularly during periods of near zero or zero flow	o negligible; water levels at the intake are controlled by Ontario Hydro operations downstream; an adequate source will be available at all times; the proposed rate of water taking by OWMC will not affect river water levels measurably	o none required
o accidental release of contaminated surface runoff could impair downstream water quality	o probability of impairment of Welland River from unrecovered release of contaminated surface water is very low (approx. 0.01 over life of the facility, equal to a frequency of occurrence of approximately once every 5400 years)	o appropriate controls to be incorporated into OWMC emergency response plan; these include: - downstream notification of water users in event of a release - provision of temporary alternate water supply - remedial action (spill containment and/or clean-up)

CHAPTER 7
IMPACT MANAGEMENT, MONITORING AND FACILITY DECOMMISSIONING

The increases in peak flow, runoff volume and erosion described previously may not be acceptable to downstream residents or to the Niagara Peninsula Conservation Authority (NPCA), without implementation of proper impact management measures. Proposed measures are identified and described in this section.

7.1 IMPACT MANAGEMENT - WATER QUANTITY

7.1.1 RUNOFF CONTROLS

7.1.1.1 Control of Site Discharge

If all seven of the existing outlets from the site were to be maintained under post-development runoff conditions, improvement works could be required along each outlet from the site to the Welland River. This is not a practical solution considering the cost of channelization and erosion works required along with the disruption to numerous private properties and the need for easements and maintenance. Therefore, instead of maintaining the

existing outlets, all site runoff will be routed to one outlet at the south end of the site. The assessment of alternative outlets for storm runoff is described in Section 7.1.1.2 while the need for a storm water management pond upstream from this outlet is discussed in Section 7.1.1.3.

7.1.1.2 Outlet Assessment

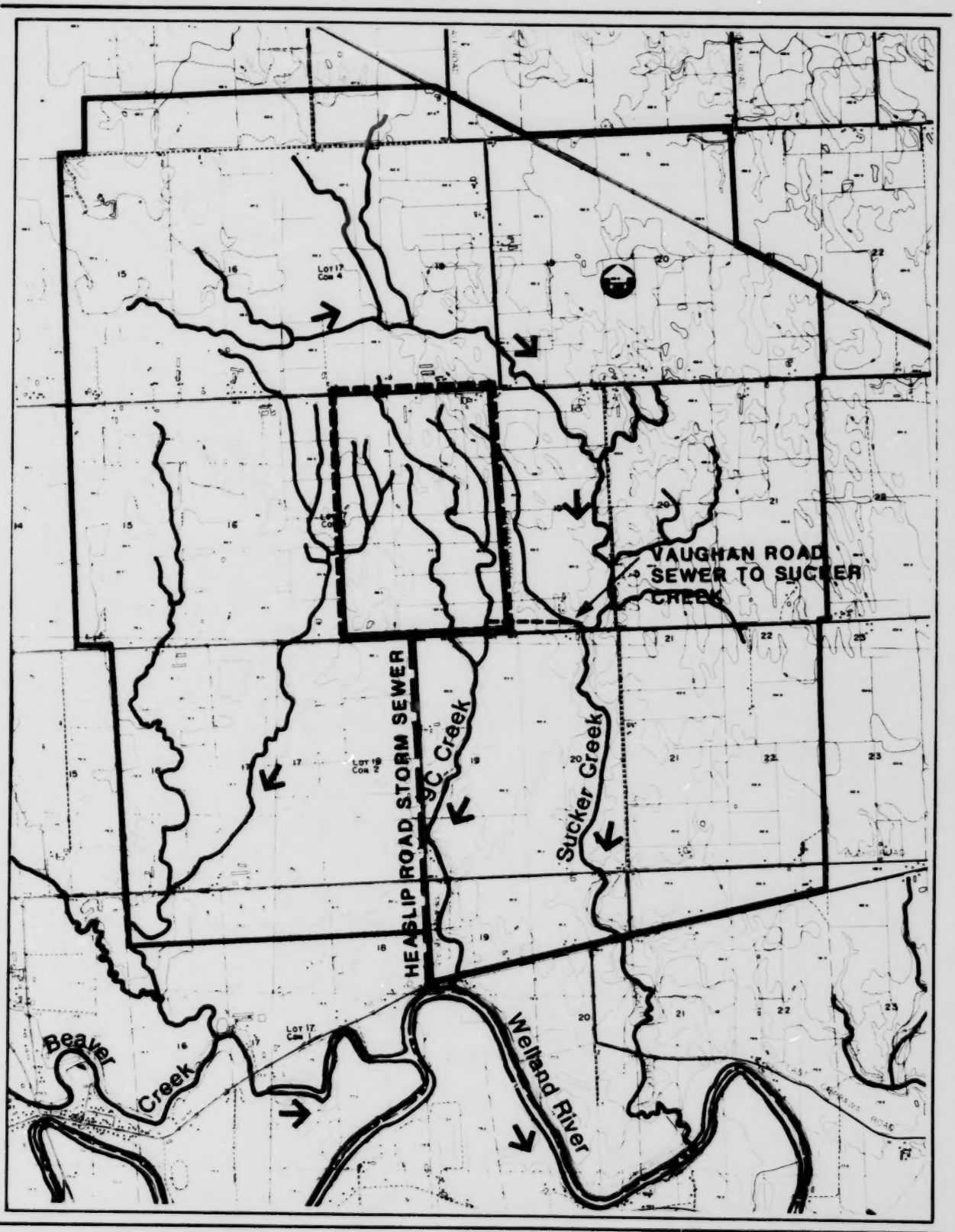
The routing of all runoff to the south end of the site requires the selection of an outlet to convey this runoff from the site southward to the Welland River. An assessment indicated that the following three outlets are available:

i) Sucker Creek
ii) 9C Creek
iii) Heaslip Road storm sewer

All three potential outlets are shown on Figure 7.1.

Sucker Creek drains lands to the north and east of the site. It outlets to the Welland River approximately 3 km south of the site. It presently drains approximately 4% of the total site area. Under the proposal to use Sucker Creek as the outlet for all site runoff, a storm sewer would be constructed from the southeast corner of the site to Sucker Creek along the north side of Vaughan Road. The creek would then be improved from Vaughan Road to the Welland River to accommodate this additional runoff.

9C Creek drains approximately 70% of the existing site area. This creek discharges directly to the Welland River approximately 2 km south of the site. This alternative would require channelization of 9C Creek from the site to the Welland River.



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ALTERNATE STORMWATER OUTLETS FROM THE SITE

FIGURE 7.1

The third alternative involves the construction of a 2 km long storm sewer along Heaslip Road from the site, south to the Welland River.

Table 7.1 provides a listing of relevant technical data for the three options and includes the type of facility, length, slope, design criteria and approximate sizing together with approximate land requirements and total capital cost (excluding land).

Table 7.2 presents a simple matrix comparison of the three alternatives for a number of factors and indicators. The Heaslip Road storm sewer has several significant advantages. These include:

- ability to readily accommodate gravity drainage from the site;
- best efficiency of land use, with the storm sewer located in the existing road allowance (i.e. no land purchase and no additional lands taken out of agricultural production);
- no modification of existing watercourses with associated impact on local agricultural operations and on the natural environment;
- no negotiation required with downstream land-owners regarding temporary and permanent easements for construction and maintenance.

Therefore, on the basis of data presented in Tables 7.1 and 7.2, the Heaslip Road storm sewer is the preferred outlet for storm water runoff from the site. This assessment was confirmed based on input from several technical disciplines in the Environmental Assessment Report (OWMC, 1987).

TABLE 7.1

FACTS AND FIGURES ON ALTERNATIVE STORM WATER OUTFALLS

Features	Option 1 Sucker Creek - Storm Sewer and Channelization	Option 2 Heaslip Road - Storm Sewer to Welland R.	Option 3 Channelize 9C Creek	Comments
o Major Receiving Watercourse	Welland River	Welland River	Welland River	-
o Immediate Receiver	Sucker Creek	Welland River	9C Creek	-
o Length of Gravity Sewer	500 m	2000 m	N/A	-
o Maximum Length of Channelization	3500 m	N/A	2200 m	Lower end of watercourses may not require channelization
o Assumed Design Flow for Channelization	500 cfs (14.2 m^3/s)	N/A	65 cfs (1.8 m^3/s)	Channel design flow for Sucker Creek includes runoff from upstream drainage area
o Assumed Design Flow for Gravity Sewer	65 cfs (1.8 m^3/s)	65 cfs (1.8 m^3/s)	N/A	-
o Assumed Available Gradient	0.2%	0.2%	0.2%	Allows for depth of channel/sewer and tailwater conditions in Welland River
o Size of Gravity Sewer	48"Ø	48"Ø	N/A	For comparative evaluation only; based on 65 cfs @ 0.2% slope
o Approximate channel sizing:				
- bottom width	10' (3 m)	N/A	5' (1.5 m)	Trapezoidal channel shape assumed
- depth	6' (1.8 m)	N/A	3' (0.9 m)	Average water depth at design flow excluding freeboard
- side slopes	2.5H:IV	N/A	2.5H:IV	Subject to soil stability
- typical top width	50' (15.2 m)	N/A	30' (9.1 m)	For Option 2, storm sewer in existing road allowance
o Approximate Land Requirements	18.5 ac (7.5 ha)	N/A	8.3 ac (3.4 ha)	Channelization assumed for full length to outlet at Welland River; assumed width of land at 20' (6 m) greater than typical channel top width.
o Number of Road Crossings/ Culverts	4	3	3	Includes Vaughan Road; all road crossings may not require upgrading
o Approximate Capital Cost	$1,600,000	$980,000	$625,000	Worst case for Sucker Creek; includes channel upgrading for existing flows from large upstream drainage area, in addition to site runoff diverted to creek; excludes cost of land purchase for Options 1 and 3

TABLE 7.2

COMPARATIVE EVALUATION OF ALTERNATIVE STORMWATER OUTFALLS

Factors	Indicators	Option 1 Sucker Creek	Option 2 Heaslip Road	Option 3 9C Creek	Remarks
PERFORMANCE	Effect on drainage efficiency/capacity	Upgrade natural drainage efficiency/-capacity of Sucker Creek	No change to existing watercourses	Upgrade natural drainage efficiency/capacity of 9C Creek	
	Change in Natural Drainage Patterns	Diversion of 9C Creek drainage to Sucker Creek	Diversion of 9C Creek drainage directly to Welland River	Existing drainage pattern essentially maintained	Normally prefer to maintain existing drainage patterns wherever possible
	Ability to accommodate gravity drainage from landfill	Good; available gradient allows depth of storm sewer to be adjusted to accommodate gravity drainage	Good; same as for Option 1	Gravity drainage may necessitate deep channel in proximity to site requiring increased excavation, land and associated cost	
	Efficiency of land use	Least efficient; requires approx. 7.5 ha of agricultural and valley lands for channelization	Most efficient; utilities in existing road allowance; no additional agricultural land taken out of production	Channelization removes approx. 3.4 ha of cropland from production	Land requirements assume channelization of watercourses for entire length to outlet at Welland River
	Potential for quality impairment of local watercourses	Increased for Sucker Creek from sewer outfall to Welland River	None	Increased for 9C Creek from site boundary to Welland River	Potential of quality impairment of Welland River considered equal in all cases
	Disruption of downstream water use(s)	Reduce volume and duration of active period on 9C Creek; corresponding increase on Sucker Creek	Reduce volume and duration of active period on 9C Creek	Essentially no change; maintains existing flow pattern	Downstream water uses to be confirmed All watercourses intermittent
RELIABILITY	Long-term maintenance requirements	Some; periodic cleaning of channel; possible repair of areas of erosion	Virtually none; eventual replacement of storm sewer in very long-term	Some periodic cleaning of channel; possible repair of areas of erosion	
	Regular maintenance requirements (during operations)	Similar to long-term requirements above	Virtually nil	Similar to long-term requirements above	

TABLE 7.2

COMPARATIVE EVALUATION OF ALTERNATIVE STORMWATER OUTFALLS

(continued)

Factors	Indicators	Option 1 Sucker Creek	Option 2 Heaslip Road	Option 3 9C Creek	Remarks
RELIABILITY (cont'd)	Vulnerability to interruption	Low; possible reduction in channel capacity in winter with snow and ice	Minimal	Low; possible reduction in channel capacity in winter with snow and ice	
	Overall operational reliability	High with gravity drainage system	Very high with gravity drainage system	High with gravity drainage system	
SAFETY	Risk to public	Some risk to public safety with open channel during high flow periods	Virtually nil; facility inaccessible to public	Some risk to public safety with open channel during high flow periods	
FLEXIBILITY	For capacity expansion	Open-ended for capacity expansion, if required, with channel widening	Limited to surcharged capacity of storm sewer	Open-ended for capacity expansion, if required, with channel widening	Unlikely that capacity increase will be required
IMPLEMENTATION	Effects of Construction	Degradation/alteration of existing land and aquatic environment	Construction limited to existing road allowance; potential for temporary traffic disruption; construction impacts common to other utilities proposed in road allowance	Degradation/alteration of existing land and aquatic environment	
COST	Capital Cost	$1,600,000	$980,000	$625,000	Excludes land purchase cost for Options 1 and 3
	Operating cost	Low	Virtually nil	Low	Not a significant factor with gravity drainage system

7.1.1.3 Landfill Storm Detention Pond

At the outset of this study, the potential need for a storm detention pond at the south end of the site was identified on the basis of the following:

i) need to eliminate impacts of flow increases on immediate receivers (Beaver Creek, 9C Creek, Sucker Creek);

ii) need to eliminate impacts of flow increases on the ultimate receiver (Welland River);

iii) potential to reduce the magnitude of downstream works required to convey site runoff to the Welland River;

iv) to retain and test surface runoff for contamination prior to release downstream (contingency only).

With the diversion of all site runoff to a storm sewer along Heaslip Road (as described in Section 7.1.1.2), the concern created by item i) above is eliminated (i.e. there is no potential for increased flooding or erosion on the immediate receivers).

Regarding item ii) above, it was shown in Section 6.1.1.3 that even without mitigation measures, impacts of peak flow and volume increases on the Welland River are minor.

Item iii) above refers to the benefit which would be derived in terms of reduced storm sewer sizing, if a storm water control pond is implemented on-site. The larger the pond provided, the smaller the outlet sewer required along Heaslip Road. The pond size does not affect the total site area available for landfilling provided that the storm detention pond is relocated on top of a completed portion of the landfill in future. An analysis of pond size versus storm sewer size is presented in Section 7.1.1.4.

Item iv) relates to the risk of contaminated surface water leaving the site. While this risk is very low (Battelle, 1987), under emergency conditions it may be possible to retain runoff temporarily on-site. The outlet sewer could be equipped with an automatic/manually operated gate which can be closed if contamination of surface runoff is indicated or even suspected. This could involve use of pond freeboard and possibly flooding part of the south end of the site for extreme events.

7.1.1.4 Outlet Size Versus Pond Area Requirements

The size of the outlet sewer along Heaslip Road will have a significant impact on the pond area required. The greater the capacity of the outlet sewer, the lower will be the pond area requirements.

The capacity of various storm sewer sizes was based on the head loss equation given below:

$$H_L = \left(1 + ke + \frac{19.6n^2L}{R^{1.33}}\right)\left(\frac{V^2}{2g}\right)$$

Where:
- H_L = total available head loss (m)
- k_e = entrance loss coefficient (0.3)
- n = Mannings "n" value (.013)
- L = storm sewer length (2075 m)
- R = wetted perimeter (m)
- V = velocity of flow (m/s)
- g = gravitational constant (9.8 m/s^2)

The available head loss (H_L) is given by the difference between the 1:100 year Welland River tailwater elevation and the maximum allowable water surface elevation in the pond. The Welland River tailwater elevation of 175.4 m was obtained from the

Welland River Study (Dillon, 1985). The maximum on-site pond water surface elevation of 182 m was selected giving a 1 m freeboard below existing ground elevation of approximately 183 m. It will also allow the perimeter ditches to drain freely to the pond without back-up.

On the basis of the assumptions presented above, Table 7.3 was developed to illustrate the capacity of various diameter storm sewers. This data is presented graphically on Figure 7.2. Also indicated on this figure are the existing and post-development flow estimates and pipe sizes required to convey these flows. The minimum storm sewer outlet is assumed to be 600 mm Ø (24 in.). The pipe size required to convey the existing conditions flow estimate of 2.06 m^3/s is 1200 mm Ø (48 in.) while the size required to convey the uncontrolled post-development flow of 11.15 m^3/s (from site only - external areas not included) is 2250 mm Ø (90 in.). Reduction in the size of this 2250 mm Ø sewer requires reduction in outflow by way of an on-site storm water detention pond.

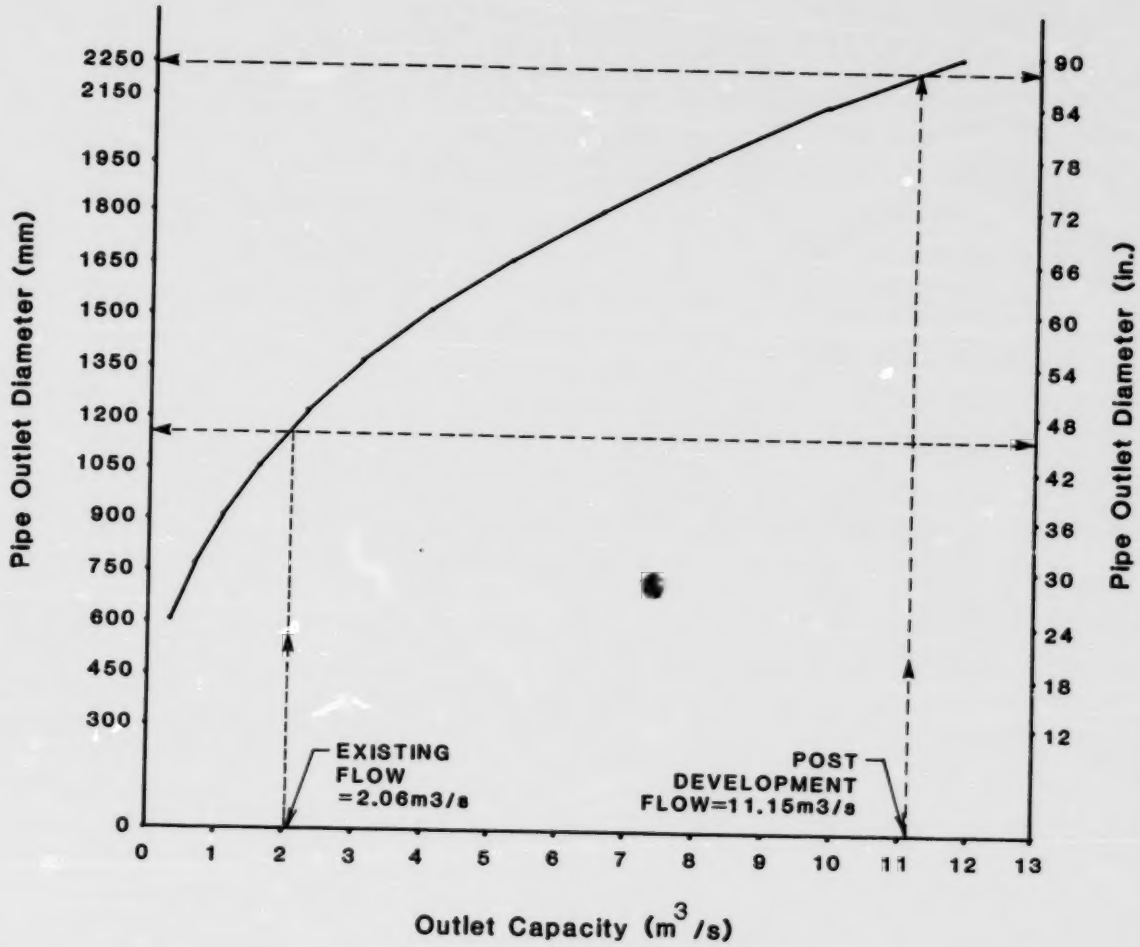
For reasons of safety, and in recognition of hydrogeologic constraints on the depth of the pond, the pond invert has been limited to elevation 180 m. This provides a design water depth of 2 m and a total pond depth of 3 m below existing ground (183 m). The pond would be generally located at the south end of the site between the COA and the perimeter berm. A maximum pond width of about 105 m can be constructed in this area and has been assumed for all analyses.

TABLE 7.3
STORM SEWER CAPACITIES

Sewer Diameter (mm)	Sewer Diameter (in.)	Capacity m^3/s
600	24	0.36
750	30	0.65
900	36	1.06
1050	42	1.59
1200	48	2.26
1350	54	3.08
1500	60	4.07
1650	66	5.23
1800	72	6.57
1950	78	8.10
2100	84	9.84
2250	90	11.78

Notes:

i) Capacities based on outlet control
ii) Welland River tailwater = 175.4 m
iii) Maximum allowable pond water surface elevation = 182 m
iv) Storm sewer length = 2075 m.



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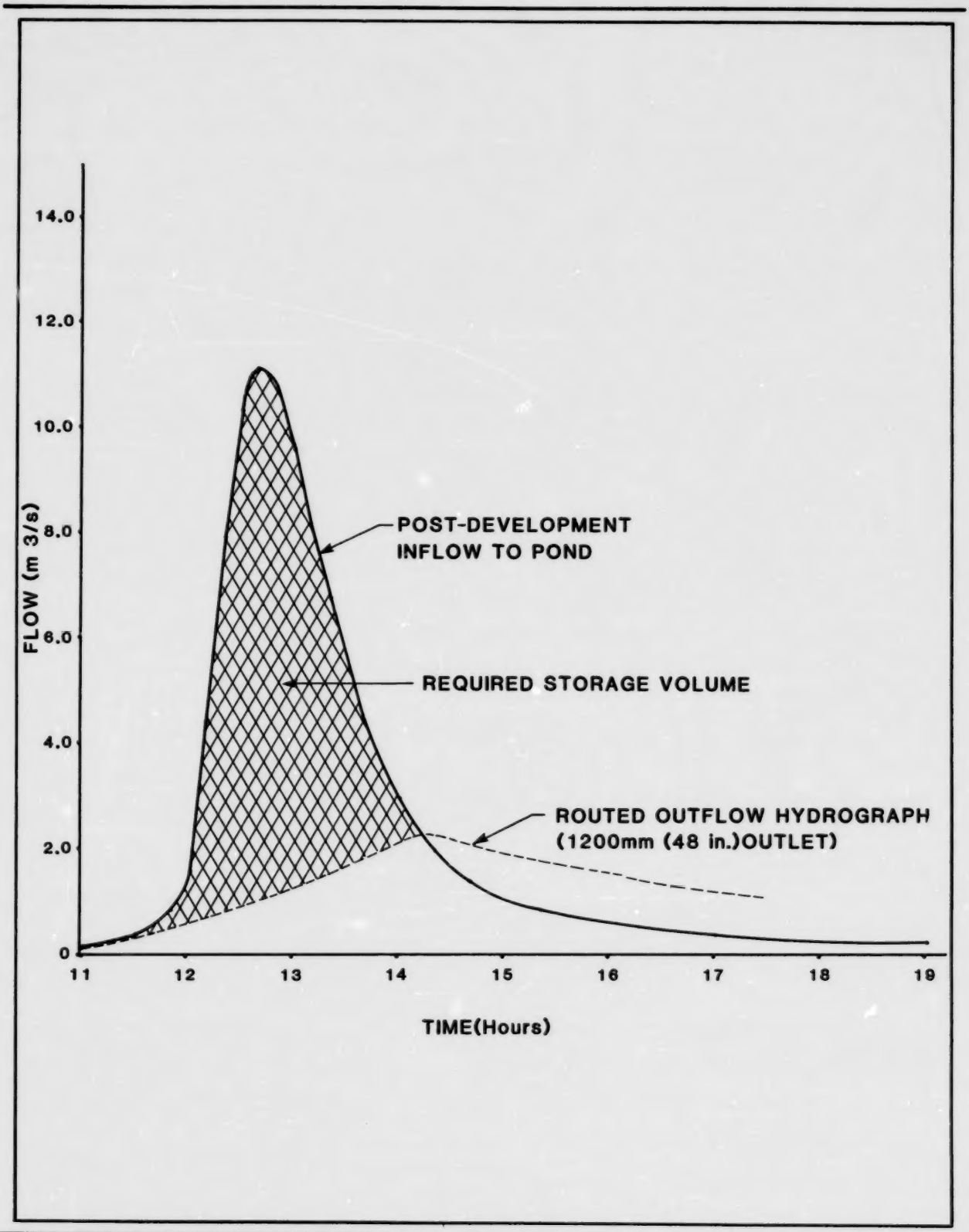
STORM SEWER CAPACITY

FIGURE 7.2

Required storage volumes have been estimated on the basis of the various storm sewer capacities and the residual volume under the post-development flow hydrograph. An example of this volume estimate is shown on Figure 7.3. For illustration, a 1200mm Ø (48 in.) outlet sewer has been selected. From Table 7.3, the 1200 mm Ø sewer has a capacity of 2.26 m^3/s. The estimated routed hydrograph with a maximum outflow of 2.26 m^3/s is shown on Figure 7.3. The cross-hatched area shown on the figure represents the pond storage volume required to limit the outflow to 2.26 m^3/s at a maximum allowable pond water surface elevation of 182 m. The same methodology was used to derive the storage volumes required with the entire range of outlet sewer sizes. This information is presented in Table 7.4. Also presented on this table are the associated pond areas and dimensions. Figure 7.4 has been developed from the data presented in Table 7.4. The example shown on this figure indicates that a 1200 mm Ø outlet sewer will convey a flow of 2.26 m^3/s but requires a pond area of approximately 3.1 ha. The pond areas required for various storm sewer outlet sizes are shown in plan on Figure 7.5. While this figure assumes a rectangular pond shape, the actual pond shape is somewhat flexible and can be modified to accommodate other site requirements, if required.

Based on this evaluation, a 1200 mm Ø storm sewer located on Heaslip Road is the preferred means of conveying storm runoff from the site to the Welland River. This sewer size limits the future outflow from the detention pond (for the 100 year return period storm) to approximately the same level as the existing 1:100 year peak flow. Accordingly, the potential increase in peak flows and runoff volumes for infrequent storm events with site development, will not increase water levels and flooding potential for flood susceptible areas on the lower Welland River.

While higher release rates might be tolerable (based on the impact analysis in Section 6.1.1.3), significant additional cost would be required to provide additional conveyance capacity between the site and the Welland River.



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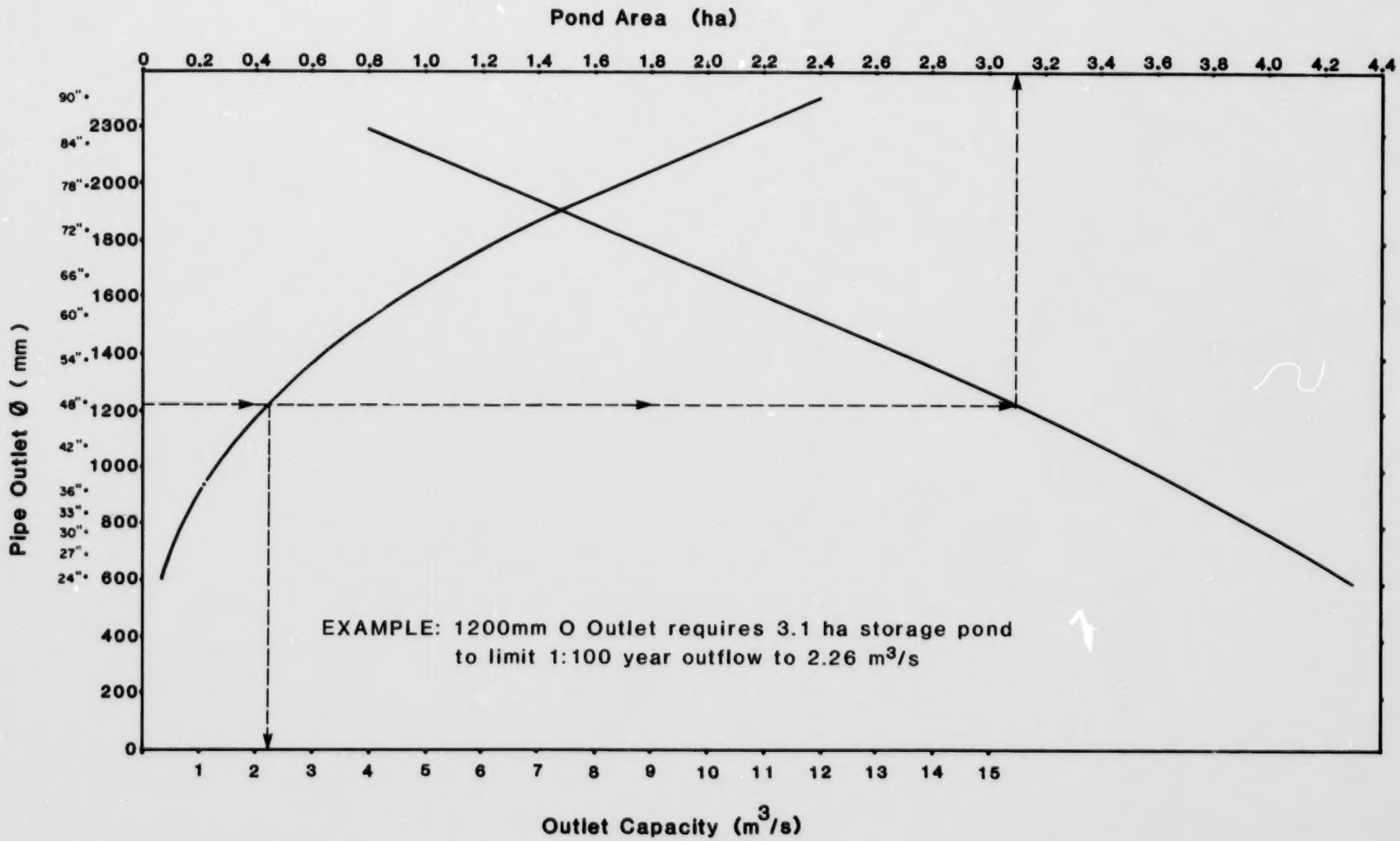
POND VOLUME ESTIMATION

FIGURE 7.3

TABLE 7.4
POND REQUIREMENTS FOR VARIOUS STORM SEWER SIZES

Diameter (mm)	Diameter (in)	Allowable Capacity (m^3/s)	Required Storage Volume (m^3)	Area of Pond (ha)	Dimension of Pond (m)
600	24	0.360	59,300	4.28	408 x 105
675	27	0.493	56,902	4.11	391 x 105
750	30	0.651	55,741	4.03	384 x 105
825	33	0.838	53,419	3.86	368 x 105
900	36	1.056	51,677	3.74	356 x 105
975	39	1.305	47,902	3.47	331 x 105
1050	42	1.589	45,870	3.32	316 x 105
1200	48	2.260	42,967	3.11	296 x 105
1350	54	3.084	37,625	2.73	260 x 105
1500	60	4.069	32,051	2.33	222 x 105
1650	66	5.227	26,883	1.96	187 x 105
1800	72	6.570	23,225	1.70	162 x 105
1950	78	8.101	17,302	1.27	121 x 105
2150	84	9.837	12,715	0.95	90 x 105
2250	90	11.780	-	-	-



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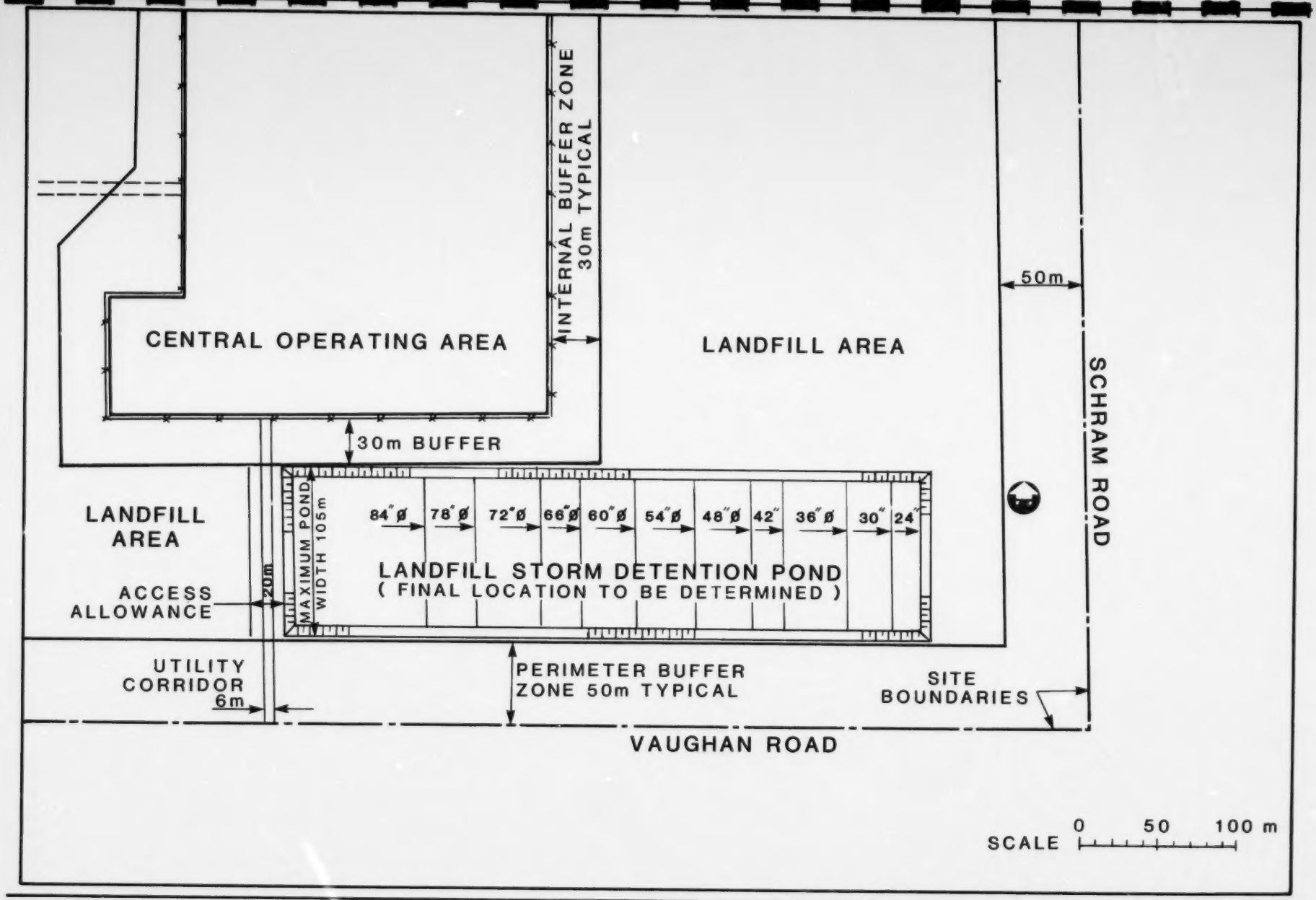
PIPE OUTLET VERSUS POND SIZE

FIGURE 7.4



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POND SIZE REQUIRED FOR VARIOUS OUTLET SIZES

FIGURE 7.5

In summary, mitigation measures to control peak flows include:

i) routing of all site runoff to one outlet at the south end of the site;

ii) provision of berms around the COA and landfill areas to ensure runoff from these and external areas are segregated and managed separately;

iii) 1200 mm Ø storm sewer along Heaslip Road for conveyance of all site runoff to the Welland River;

iv) landfill storm detention pond (approximately 300 m x 100 m) at the south end of the site to reduce the magnitude of downstream works (Heaslip Road sewer), limit post-development flows to near pre-development levels and to provide a location for testing and containment of runoff prior to release downstream under unusual conditions; detention pond shape can be modified to accommodate siting constraints.

7.1.2 SURFACE WATER USE

As noted in Section 6.1.3, limited use is made of local, intermittent watercourses downstream of the site for seasonal watering of livestock. Diversion of site runoff to the Welland River will reduce the magnitude and duration of the active period of flow, particularly on 9C Creek. While the impact of the diversion of site drainage on surface water use is considered minor, because of the intermittent nature of the local watercourses and the very limited use of these surface waters (three properties), opportunity for replacement of supply readily exists from the proposed raw water line on Heaslip Road.

7.2 IMPACT MANAGEMENT - WATER QUALITY

7.2.1 EROSION AND SEDIMENT CONTROLS

7.2.1.1 General

The estimated annual soil loss values presented in Table 6.3 (Section 6.2.1) suggest that mitigation measures are required during the initial construction period and over the operational period when landfill development is proceeding. The mitigation measures available can be broadly categorized as follows:

i) vegetative cover
ii) non-vegetative cover
iii) slope modification
iv) structural erosion controls.

The application of these measures to the Preferred Site as a means of minimizing erosion and soil loss is described in Sections 7.2.1.2 to 7.2.1.6 below. Preparation of an erosion control plan is recommended during design of the facilities.

7.2.1.2 Vegetative Cover

Once suspended in water, the clay colloids characteristic of the Preferred Site are difficult to settle out and would tend to remain in suspension indefinitely. Therefore, it is imperative that the area and length of time that soils remain exposed be minimized, and erosion be controlled at the source. This can best be achieved using a vegetative cover, since it is effective in the long-term and relatively inexpensive. The main drawback of erosion control using a vegetative cover is its ineffectiveness in the early stages (just after seed application). However, this problem can be overcome by applying a seed, fertilizer and mulch mixture to all areas as soon as final grading is achieved and topsoil placed. The mulch will serve the dual purpose of

immediately providing protection to the bare soil and also with providing a good environment for germination of seed and grass growth. Alternatively, a variety of stabilization mats are available for the same purpose.

The value of a vegetative cover is illustrated by the results presented in Table 6.3. It is estimated that under existing and future (post-closure) conditions, soil loss will take place at an annual rate of approximately 0.2 t/ha. In the interim, when the vegetation is removed from portions of the site, soil loss is estimated to take place at a rate of about 20 t/ha. Also, the annual loss rate from unvegetated berms, ditches and stockpiles of 300-900 t/ha, can be reduced substantially (to 3 - 9 t/ha) with the application of seed, fertilizer and mulch and eventual attainment of a good grass cover.

Therefore, application of seed, fertilizer and a mulch cover will decrease the potential soil loss rate by a factor of one hundred. The staged operation of the landfill will also act to minimize erosion by ensuring that the exposed areas are kept to a minimum. Although the estimated loss rate from the unvegetated berms, ditches and stockpiles is relatively large, the actual environmental effect will likely be minor. These areas comprise a relatively small portion of the total site area and they can be seeded and mulched immediately after construction. Construction of these initial works should be timed such that optimal vegetative cover can be rapidly established.

7.2.1.3 Non-Vegetative Cover

Non-vegetative covers are required when areas cannot be revegetated immediately after completion of landfilling. Rather than subjecting a large unprotected bare soil area to the elements through the non-growing season, a temporary non-vegetative cover

should be applied. These covers could comprise hydraulic or straw mulches with adhesives, chemical mulches, hardwood chips or plastic sheeting. It is anticipated that the unprotected areas will be large enough that only the hydraulic and straw mulches can be practically applied.

7.2.1.4 Slope Modification

Erosion from the site can be minimized by maintaining mild overland flow and ditch gradients. Because of the hydrogeologic constraint requiring that the final landform height be similar to existing, overland slopes will be limited to about 2%. The berm and ditch side slopes are much steeper (3:1 and 2:1 respectively) but their limited height and depth (both 1 m) result in overland flow lengths of only 3 and 2 m respectively. This, combined with the fact that they will be seeded and mulched immediately after construction suggests that the total soil loss from those areas will be minor. Therefore, side slopes with milder gradient cannot be justified at the expense of greater area requirements for their construction.

Because of the flat nature of the site, it is anticipated that longitudinal ditch slopes will be limited to approximately 0.1%. This is a very mild gradient and will not likely require any channel lining other than grass.

In summary, overland flow slopes have been minimized to ensure that the final landform does not exceed the height restrictions imposed by hydrogeologic constraints. Also, longitudinal ditch slopes have been minimized due to the limited fall across the site. Both of these conditions act to discourage erosion and soil loss from the site. The only areas where slopes could be reduced are the berm and ditch side slopes. However, the overland

flow lengths and areas associated with these side slopes are so small and the time of bare soil exposure so short, that the additional land area required to decrease these side slopes cannot be justified.

7.2.1.5 Structural Sediment Control Measures

Mitigation measures described above represent attempts to reduce or eliminate altogether the occurrence of erosion. However, recognizing that at any construction site, some erosion will occur regardless of the mitigation measures used, it is considered necessary to provide for sediment control so that much of the eroded material can be prevented from leaving the site.

The following means are available for on-site sediment control:

i) vegetated buffer strips;
ii) sediment barriers;
iii) check dams;
iv) sediment traps;
v) sediment basins.

The application of each of these sediment control options to the Preferred Site is discussed below.

Vegetated Buffer Strips

Vegetated buffer strips placed perpendicular to the direction of flow provide a simple, effective and economical method of sediment control.

The initial construction, seeding and mulching of the perimeter ditching around the site should provide an effective vegetated buffer strip once an adequate cover is achieved. To

ensure that an adequate cover is achieved, the ditch invert may have to be sodded rather than seeded and mulched. As landfilling proceeds, runoff from unprotected (bare soil) areas of the completed landfill will be conveyed through the previously vegetated perimeter ditch area and significant sediment removal is likely. This will require some over-sizing of the perimeter ditching to accommodate this sediment deposition without adversely affecting the ditch capacity.

Soil stockpiles will be located on undisturbed areas where vegetation already exists. Therefore, runoff from the soil stockpiles will follow a vegetated overland flow path and this should provide a benefit in terms of limiting the amount of sediment that reaches the site outlet.

Sediment Barriers

To reduce the potential soil loss prior to obtaining a good grass cover, the perimeter berms and stockpiles should be encircled with staked straw bales. The purpose of straw bales is to intercept and detain sediment generated from small unprotected areas.

Normally, straw bale dykes are used when (USEPA, 1976):

a) there is no concentration of water in a channel above the barrier;

b) erosion would occur in the form of sheet or rill erosion;

c) contributing area is less than 0.2 ha and the length of slope above the dyke is less than 30 m.

Thus, the straw bale system is suitable for control of sediment from the perimeter berms and stockpiles. Each bale should be wire or nylon bound and staked slightly below grade (approximately 0.1 m) to form a continuous berm at the toe of the slope.

Other types of sediment barriers which may be considered in final design include geotextile silt fences, burlap silt fences and filter berms.

A geotextile silt fence consists of a wire fence to which a filter fabric is attached on the upstream side. This combination should be secured to fence posts spaced 3 m apart.

A burlap filter barrier is a low-cost silt fence, constructed with burlap as the filter material and attached to posts at 1 m centres. This type of barrier has a slightly shorter useful life than the geotextile barrier described above. However, since the purpose of these barriers is to provide interim protection only until a vegetative cover is achieved on the areas they are protecting, an extended useful life does not provide significant benefit.

Filter berms generally consist of permeable gravel or crushed stone to filter out sediment while permitting water to pass through. A filter cloth may be incorporated into the upstream face to improve filter efficiency.

All of the sediment trapping methods described above apply to the removal of sediment from overland (sheet) flow only. Therefore, they would be ideal for application at the toe of slopes of perimeter berms and stockpiles. As they all have a relatively short life, they are to be used as an interim measure until a vegetative cover can be achieved on upstream areas.

Check Dams

A check dam is an obstacle to flow constructed in a ditch, to decrease flow velocity, thereby encouraging sediment deposition upstream. They are useful as a back-up to source erosion and sediment control measures including the vegetative cover and buffer strips and silt fences described previously. They can be constructed of straw bales, sand bags, loosely mounded rock or gabions, depending on the length of time they will be in place and the anticipated flow they will have to pass. One or more check dams should be constructed in each perimeter ditch and can be eliminated as upstream areas become fully vegetated. These dams must be monitored regularly and sediment removed if there is significant accumulation (i.e. one-third the height of the dam).

Sediment Traps

A sediment trap comprises a small, shallow pit excavated within a ditch or channel to trap and store sediment carried by runoff from upstream areas. Sediment traps provide a very practical form of protection during initial construction periods and prior to the achievement of a good vegetative cover over the erodible area upstream. These traps can be made more effective by using them in conjunction with the check dams described above. They can be located within the perimeter ditches immediately downstream from disturbed landfilling areas and filled in and graded over as final vegetative cover is achieved. The trap depth should not exceed 1 m and they should be cleaned out when sediment accumulates to one-half the trap depth.

Sediment Basins

Sediment basins differ from sediment traps by their much larger size, higher standard of design and construction and hence greater cost. These basins are usually considered when other measures are not sufficient or are ineffective in limiting the amount of sediment leaving the site. Generally, a sediment basin will not

be highly effective in removing the fine clay particles characteristic of the Preferred Site area. Once suspended, these clay particles will be very difficult to settle out.

Therefore, given the anticipated limited effectiveness of sediment basins at this site, and the alternatives available for erosion and sediment control at the source (described previously), sediment basins are not proposed for the Preferred Site. However, the erosion/sedimentation conditions should be monitored during the initial years of the facility development to determine if further control measures are required. If additional control measures are considered necessary, the proposed storm water management pond at the south end of the site can be converted to serve both storm water and sediment control functions by modifying the outlet structure.

Other Controls

The routing of all storm water runoff from the site to one outlet (as described in Section 7.1.1.2), will be very effective in eliminating erosion and/or sedimentation within the immediate receivers downstream (Sucker Creek, 9C Creek, Beaver Creek tributaries). Therefore, conveyance capacity and hence flooding along the immediate receivers downstream, will not be affected by sedimentation associated with on-site construction activities.

However, it is important that the proposed Heaslip Road sewer be designed to ensure that its capacity will not be adversely affected by sediment deposition within it. Self-cleaning velocities in excess of 1 m/s are required for very frequently occurring flow rates (say 1:2 year frequency). Therefore, any sediment that does leave the site will be conveyed directly to the Welland River without settling out in the outlet sewer.

7.2.1.6 Summary of Controls

Erosion and sediment control must begin at the source if the impacts of landfill operations on surface waters are to be minimized. Careful control of the area of exposed soils (through staged development) and immediate seeding and mulching of exposed slopes (and possible sodding of ditch inverts) will form the basis of the erosion control program for the site. This initial seed/mulch/sod program applies to all initially constructed works (berms, ditches, stockpiles).

Since time is required to achieve a good vegetation cover on the initial works, and because landfill operations may result in exposure of soils for extended periods of time, back-up (sedimentation inducing) measures are also required. These measures include:

i) leaving as much of the existing, vegetated area as possible undisturbed until it is required for landfilling.

ii) placement of sediment barriers (straw bale dykes) at the toe of stockpile, berm and other slopes to intercept and filter sediment from overland runoff;

iii) construction of check dams at several locations within the perimeter ditches;

iv) construction of sediment traps, possibly in conjunction with check dams described above, to trap and store sediment;

v) modification of storm detention pond outlet to serve the dual purpose of storm water and sediment control (contingency only if short-term monitoring indicates need).

The program described above will ensure that impacts of site erosion on the ultimate receiver (Welland River) are minimal. That the impacts will be minimal is supported by the fact that erosion and transport of sediment from the very large (548 km^2) and highly agricultural Welland River watershed will likely be several orders-of-magnitude greater than that which could occur from the relatively small (1.24 km^2) site area, even without controls. However, to ensure the river quality is not further degraded, the above program is recommended.

The above program has been developed for the ultimate receiver (Welland River), but will not benefit the immediate receivers (Sucker Creek, 9C Creek and the Beaver Creek tributaries). Impacts on immediate receivers resulting from erosion and sedimentation have been eliminated by routing all site runoff to the Welland River via the proposed Heaslip Road storm sewer.

7.2.2 ACCIDENTAL RELEASE TO SURFACE WATER

As previously discussed, several specific management features are proposed for the facility which will minimize the opportunity for release of contaminants to the surface water environment. Nevertheless, a very small risk does exist for the accidental discharge of contaminated storm water from the COA into the Welland River (Section 6.2.3).

While the landfill storm detention pond at the south end of the site is essentially a flow-through system, periodic testing of runoff quality should be conducted to confirm that contamination of surface drainage from the completed landfill and from undeveloped parts of the site is not occurring. Several possible contingency measures have been identified for inclusion in OWMC's emergency response plan. These include:

- notification of downstream water users if river contamination is known or suspected;

- provision of alternative water supplies where needed, in the event of contamination;

- in the event of a spill, spill clean-up for contaminants which sink to the river bed or float on the water surface;

- closure of shut-off gate/valve in outlet sewer to prevent the release of storm water suspected of being contaminated;

- testing of storm water and treatment, if necessary.

7.3 LONG-TERM MONITORING

7.3.1 INTRODUCTION

Surface water quality studies carried out in 1986 provide the baseline data on surface water quality at the West Lincoln site. The studies are required in order that potential impacts can be identified and mitigative measures planned to ameliorate the impacts. Once physical works start on the site and the facility eventually operates, this water quality study will form the background data against which the real impacts are assessed and the effectiveness of mitigative measures are judged. The continued study of the water quality at the facility is the means of assessing the impacts. This continued study becomes the surface water monitoring program for the facility as it is constructed and operated.

7.3.2 APPROACH

There are three basic elements to the surface water monitoring program. Two deal with the storm water discharge, the other deals with the receiving waterway. Storm water discharge can be either storm water runoff from the central processing area of the OWMC facility or storm water runoff from the buffer zone and completed landfill areas. In the former case it is assumed that this runoff requires testing before discharge to assure non-contamination. The interrelation of these elements is influenced by two factors. First, the OWMC facility's design minimizes the amount of water discharged and, second, the receiving body (Welland River) is large compared to the proposed storm water discharge. The overall strategy for the storm water discharge should be continuous real-time monitoring. On the Welland River, regular grab sampling should be practised taking water from the well-mixed zone downstream of the storm water outfall. Upstream water quality on the Welland River should also be assessed in the same time frame as the downstream sampling to account for regional sources of contamination.

In times of low flow in the Welland River, storm water discharged may not be well-mixed with the river water. Storm water flow and receiving water flow should be monitored continuously. A few simple parameters will likely be appropriate for the storm water monitoring in real time. Continued advancement in instrumentation dictates that the final selection of the parameters be deferred until closer to the start of construction. More comprehensive sampling will be practised in the Welland River and on the storm water on a weekly, monthly or yearly basis depending on the parameter. It is likely that sampling frequency, protocol, analysis methodology and discharge limits will be defined by regulations arising out of the Municipal-Industrial Strategy for Abatement (MISA) initiative. The data collected should be archived for future reference.

In general the approach to receiving water quality should be based on two fundamental tenets.

- Quality Assurance of data should be continually practised. Standard methods should be employed and continual verification and documentation of the precision and accuracy of the data should be carried out to make the whole data set comparable in time.

- Water Quality should be assessed on the basis of a complete analysis of the water so that an ion balance test can be applied to the data. Some "trace" constituents may contribute to this balance.

The total understanding of changes in water quality needs to be accomplished. The behavior of major components may not indicate problems in the short-term but trends can develop where fundamental changes may be occurring. For trace components their fate in the surface water environment needs to be understood. This also means that sediment sampling must be included in surface water monitoring.

7.3.3 MONITORING PARAMETERS

The possible monitoring parameters comprise the list of chemical parameters tested for in this study plus water quantity. The discussion below briefly summarizes the rationale for the monitoring for each class of parameters.

General Chemistry Parameters (pH, dissolved oxygen, alkalinity, major anions and cations, turbidity, total dissolved solids, conductivity). These parameters provide data on the major constituents of the surface waters including gross contaminant loadings. It will be the demonstration that this overall water composition remains in a sort of balance that will assure the public that the facility's impact is acceptable.

Nutrients (nitrogen parameters, phosphate, organic carbon). These parameters combined with some general chemical parameters (dissolved oxygen, pH, turbidity) will provide an insight into what nutrient value exists in the surface water. Combined with biological indicators, these parameters will help predict impacts and indicate what mitigation would be most effective in reducing unwanted biological activity in the surface waters.

Bacteriological Parameters. These parameters will monitor the assimilative capacity of the river and indicate direction of process improvements if unsafe levels are approached.

Trace Metals. Metals will be major components of waste streams being received at the OWMC facility. Treatment and incinerator residues are likely to contain stabilized concentrated metals and their immobilization/stability in the landfill must be assured. It is assumed that in-plant and on-site monitoring will include trace metal monitoring but the overall effluent impacts need to be assessed in the surface water. Metals in sediments are an important parameter. Careful attention to the additive effects of metal emissions will have to be monitored. The critical metal parameters will be selected after the existing background metal levels have been identified in the existing environment. A broader scan for trace metals will likely eventuate after considering the present data set. Metals selected here for analysis were based on drinking water objective lists. A broader scan can be made using multi-element scanning techniques like DCP or ICP (direct current plasma or inductively coupled plasma) atomic absorption.

Trace Organics. Organic materials as components of waste streams or as residues or fugitive emissions will be a concern at the OWMC facilities. We expect that in-plant and on-site monitoring will test for these materials. In spite of this, it may be

important to confirm the facility monitoring by testing for trace organics in the receiving watercourse. As for trace metals the existing and future background levels of trace organics will oblige OWMC to monitor for trace organics to prove or disprove the source of trace organics found in the environment. The pre-operational testing will survey the existing environment for approximately 150 trace organic chemicals. Fortunately, they are determined in simultaneous scans for sets of the longer list.

Sediments. The major monitoring requirements on sediments are for metals, nutrients and trace organics. These parameters precipitate into or are associated with sediment materials. Different testing requirements have to be used because of the nature of the material.

Quantity. Water quantity monitoring will be required on the storm water discharge and on the Welland River. This parameter relates concentration and loading.

7.3.4 PRELIMINARY SELECTION OF SITE SPECIFIC PARAMETERS

A preliminary list of parameters can be made in a generic way at this time. The present MISA initiative of the MOE is a critical factor in establishing the exact list of parameters to be monitored and at what frequency. Some suggestions are made below on the criteria that will be used in making the selection. Also, one possible priority ranking for the classes of analyses is suggested based on an understanding of the present facility design.

Three key criteria in the selection of the parameters are:

- chemical concentrations in local watercourses at or above the guidelines for ambient water quality;

- chemicals known to be handled, treated, emitted or discharged from the OWMC facility;

- chemicals with associated criteria below instrument detection limits used in this study.

Background levels of some chemicals may diminish the capacity of the receiving waters to assimilate additional loadings. These chemicals are presently being tested for; the present analysis of the baseline data identifies those that are at or above maximal values. Chemicals present in waste or residues or effluents will also be selected as specific parameters. In particular, highly noxious and/or controversial chemicals will be selected in order to provide the public an assurance of safety.

Some chemicals have not been detected but the concentration level of concern is below instrument detection limits used in this study. Other, more sensitive methods may be available on a case specific basis; they should be used on at least a screening basis to confirm the presence or absence of these contaminants.

The present plans for the OWMC facility, as understood, dictates that the major discharge will be storm water. Among the classes discussed above it is suggested the priority for monitoring may be:

- quantity
- trace organics
- trace metals
- general chemistry.
- nutrients
- bacteriological

7.3.5 SUMMARY OF LONG-TERM MONITORING

Long-term monitoring of surface water quality at the Proposed Site will involve the verification of the quality of the water that is discharged to the Welland River and the confirmation that local watercourses like Sucker Creek are not affected by OWMC operations. It is expected that effluent monitoring will be regulated in the future and the anticipated form of these regulations defines most of the monitoring approach.

Parameters to be monitored will include all those used in this study. In addition, it is recommended that a complete characterization of the water chemistry be carried out so that a comprehensive understanding of the nature of the surface water is developed. This will be important to the understanding of the fate of trace contaminants in the receiving waters. It is expected that monitoring will be staged with comprehensive analysis being used to identify sensitive parameters which will then be monitored on a regular basis. A complete analysis would continue to be done on a less frequent basis. Among the regularly monitored parameters, there will be a range of monitoring frequencies. Certain indicator parameters can be monitored essentially in real time while others will be subject to grab sampling. Flow monitoring will be an important aspect of this program.

All analysis will be subject to strict Quality Assurance (QA) procedures. QA data will become part of the monitoring data to confirm the validity of the data produced.

Sampling locations will be similar to those used for this study. Sucker Creek monitoring will be used to track local impacts of the OWMC Facility. In the Welland River, an upstream and downstream station will be required. The upstream station

should be outside the zone of influence of the OWMC discharge. The downstream station will be sited to ensure the storm water discharge is well mixed with the river water at the sampling site. The discharge itself will have to be monitored by regulation and it is important that flow be part of that monitoring.

It will be important to organize the data into clear concise presentations for use in disseminating monitoring data to the public. Clarity of presentation without a lot of confounding data will improve the acceptability of the monitoring data.

7.4 FACILITY DECOMMISSIONING

When the OWMC Facility is finally closed down, comprehensive decommissioning of the site will be required to leave the site in an environmentally safe condition.

The after-use of the Preferred Site may be passive agricultural use or no use. However, it is obvious that the final surface drainage system must be compatible with the selected after-use plan.

Presumably, some alternatives for after-use will require an efficient surface drainage system, similar to that proposed for the operational period (i.e. continuous overland flow path, swales, perimeter ditches, landfill detention pond and gravity storm sewer). Surface drainage from the COA may revert to a gravity drainage system, connected directly to the landfill surface drainage system. This option would require long-term maintenance of the storm detention pond, the pond outlet structure and the Heaslip Road storm sewer. This could entail periodic

cleaning of the ditches, pond and perhaps even the storm sewer. Confirmation of storm water quality will also require after-use monitoring.

If the chosen after-use is not sensitive to surface drainage efficiency, the site could possibly be returned to near existing state by interrupting the surface water flow paths at selected locations to promote ponding of surface water throughout the site. With development of sufficient depression storage on the site, the deep perimeter ditches and the storm detention basin could be filled in and runoff re-directed to the restricted surface outlets as at present.

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LIST OF REFERENCES

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Final report

OWMC
Ontario
Waste Management
Corporation

A provincial crown corporation

DILLON

SITE ASSESSMENT
PHASE 4B:
SURFACE WATER
VOLUME 2 - TECHNICAL APPENDICES

Prepared for
The Ontario Waste Management Corporation

Submitted By

M.M. Dillon Limited
Consulting Engineers and Planners

October, 1987

DILLON
Consulting Engineers • Planners
Environmental Scientists

OUR FILE 9925-31-1
YOUR FILE

30 October 1987

Mr. J.G. Micak
Manager, Environmental Projects
Ontario Waste Management Corporation
2 Bloor Street West
11th Floor
Toronto, Ontario
M4W 3E2

Attention: Mr. D.F. Chollak
Environmental Planner

Site Assessment - Phase 4B
Surface Water, Volume 2 -
Technical Appendices

Dear Sirs:

We are pleased to submit the final report for the Phase 4B, Site Assessment on Surface Water. The Report has been divided into three volumes as follows and presents the results of our study of baseline condition and impact assessment.

- o Volume 1 - Main Report
- o Volume 2 - Technical Appendices
- o Volume 3 - Field and Laboratory Protocols

Volume 2 (this volume) contains twelve technical appendices in support of the main report (Volume 1). A third volume details the procedures for conducting water quality sampling and streamflow measurements, quality assurance requirements and detailed analytical and laboratory quality control procedures.

We look forward to assisting you with the approvals for and implementation of this very important project.

Yours truly,

M. M. DILLON LIMITED

A.K. Mitchell

A.K. Mitchell, P.Eng.
Project Manager
Surface Water

AKM:mrb
Attach.

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APPENDIX A
PARAMETER LISTING AND DETECTION LIMITS

APPENDIX A
PARAMETER LISTING AND DETECTION LIMITS

Table A1 is a listing of the parameters selected for testing in this study and the detection limits attained by the laboratories performing the analyses. These parameters and their detection limits are discussed in Section 2.2.2

TABLE A1
PARAMETER LISTING AND DETECTION LIMITS

Parameter	Detection Limit
GENERAL CHEMISTRY	
Field	
temperature	±0.1°C
pH	±0.01
dissolved oxygen	±0.2 mg/L
conductivity	± 2 umho/cm
Collective Descriptors	
total dissolved solids	1.0 mg/L
turbidity	1 NTU
alkalinity	0.2 mg/L as $CaCO_3$
total organic carbon	0.2 mg/L
Major Cations	
sodium	0.2 mg/L
potassium	0.1 mg/L
magnesium	0.01 mg/L
calcium	0.05 mg/L
Major Anions	
fluoride	0.005 mg/L
chloride	0.01 mg/L
bromide	0.05 mg/L
nitrate	0.05 mg/L
sulphate	0.05 mg/L
phosphate	0.10 mg/L
NUTRIENTS	
ammonia	0.05 mg/L as N
total kjeldahl nitrogen	0.05 mg/L as N
total phosphorus	0.01 mg/L as P
nitrate	0.05 mg/L as N
nitrite	0.05 mg/L as N
biochemical oxygen demand	1.0 mg/L

TABLE A1
PARAMETER LISTING AND DETECTION LIMITS
(continued)

Parameter	Detection Limit
BACTERIOLOGICAL	
total coliform	0/100 mL
fecal coliform	0/100 mL
fecal streptococci	0/100 mL
background	0/100 mL
TRACE CONSTITUENTS	
Health	
arsenic	0.001 mg/L
cadmium	0.001 mg/L
chromium	0.001 mg/L
cyanide	0.004 mg/L
lead	0.001 mg/L
mercury	0.00005 mg/L
sulphide	0.001 mg/L
Aesthetic	
aluminum	0.010 mg/L
copper	0.010 mg/L
iron	0.010 mg/L
manganese	0.002 mg/L
phenols	0.001 mg/L
zinc	0.010 mg/L
PRIORITY ORGANICS	
Volatiles	
acrolein	5.0 ug/L
1,1,1-trichloroethane	1.0 ug/L
vinyl chloride	2.0 ug/L
trichloroethylene	1.0 ug/L
bromoform	1.0 ug/L
1,4-dichlorobenzene	1.0 ug/L

TABLE A1
PARAMETER LISTING AND DETECTION LIMITS
(continued)

Parameter	Detection Limit
PRIORITY ORGANICS (continued)	
Volatiles	
dichlorobromomethane	1.0 ug/L
chloroform	1.0 ug/L
benzene	0.5 ug/L
acrylonitrile	5.0 ug/L
1,2-dichlorobenzene	1.0 ug/L
chlorobenzene	0.5 ug/L
1,3-dichlorobenzene	1.0 ug/L
dichlorodifluoromethane	2.0 ug/L
1,1-dichloroethylene	1.0 ug/L
1,3-dichloropropene	1.0 ug/L
dibromochloromethane	1.0 ug/L
o-xylene	0.5 ug/L
chloromethane	2.0 ug/L
1,1,2-trichloroethane	1.0 ug/L
carbon tetrachloride	1.0 ug/L
1,1-dichloroethane	1.0 ug/L
1,2-dichloropropane	1.0 ug/L
toluene	0.5 ug/L
1,2-dichloroethane	1.0 ug/L
tetrachloroethylene	1.0 ug/L
p-xylene	0.5 ug/L
ethylbenzene	0.5 ug/L
trichlorofluoromethane	2.0 ug/L
chloroethane	2.0 ug/L
1,1,2,2-tetrachloroethane	2.0 ug/L
bromoethane	5.0 ug/L
1,2-t-dichloroethylene	1.0 ug/L
m-xylene	0.5 ug/L
Acid Extractables (mainly phenols)	
pentachlorophenol	2.0 ug/L
2-nitrophenol	5.0 ug/L
4-nitrophenol	5.0 ug/L
2,4-dichlorophenol	2.0 ug/L
2,4,5-trichlorophenol	2.0 ug/L
2,3,4-trichlorophenol	2.0 ug/L
p-chloro-meta-cresol	5.0 ug/L
phenol	3.0 ug/L

TABLE A1
PARAMETER LISTING AND DETECTION LIMITS
(continued)

Parameter	Detection Limit
PRIORITY ORGANICS (continued)	
Acid Extractables (mainly phenols) (cont'd)	
2,3,4,5-tetrachlorophenol	2.0 ug/L
2,4,6-trichlorophenol	2.0 ug/L
2,3,5,6-tetrachlorophenol	2.0 ug/L
2,4-dinitrophenol	3.0 ug/L
4,6-dinitro-o-cresol	5.0 ug/L
2,4-dimethylphenol	2.0 ug/L
2-chlorophenol	2.0 ug/L
Base/Neutral Extractables (plasticizers and miscellaneous heavy organics)	
hexachlorocyclopentadiene	1.0 ug/L
isophorone	1.0 ug/L
nitrobenzene	1.0 ug/L
bis(2-chloroisopropyl)ether	1.0 ug/L
methylphenanthrene	1.0 ug/L
dimethyl phthalate	2.0 ug/L
naphthalene	1.0 ug/L
bis(2-chloroethoxy)methane	2.0 ug/L
hexachlorobutadiene	1.0 ug/L
4-chlorophenyl phenyl ether	1.0 ug/L
di-n-butylphthalate	1.0 ug/L
2,6-dinitrotoluene	2.0 ug/L
benzidine	5.0 ug/L
2-chloronaphthalene	1.0 ug/L
butyl benzyl phthalate	2.0 ug/L
N-nitroso-n-propylamine	3.0 ug/L
di-n-octylphthalate	2.0 ug/L
bis(2-chloroethyl)ether	1.0 ug/L
2,3,6-trichlorotoluene	2.0 ug/L
diethyl phthalate	2.0 ug/L
1,2-diphenylhydrazine	5.0 ug/L
3,3'-dichlorobenzidine	5.0 ug/L
N-nitrosodimethylamine	5.0 ug/L
N-nitrosodiphenylamine	4.0 ug/L
2-chloroethyl vinyl ether	2.0 ug/L
biphenyl	2.0 ug/L
hexachlorobenzene	1.0 ug/L

TABLE A1
PARAMETER LISTING AND DETECTION LIMITS
(continued)

Parameter	Detection Limit
PRIORITY ORGANICS (continued)	
Base/Neutral Extractables (cont'd) (plasticizers and miscellaneous heavy organics)	
1,2,4,5-tetrachlorobenzene	1.0 ug/L
hexachloroethane	1.0 ug/L
diphenylether	2.0 ug/L
fluoroanthene	1.0 ug/L
1,2,3,4-tetrachlorobenzene	1.0 ug/L
1,2,3,5-tetrachlorobenzene	1.0 ug/L
1,2,3-trichlorobenzene	1.0 ug/L
1,2,4-trichlorobenzene	1.0 ug/L
4-bromophenyl phenyl ether	1.0 ug/L
2,4-dinitrotoluene	2.0 ug/L
bis(chloromethyl)ether	1.0 ug/L
2,4,5-trichlorotoluene	2.0 ug/L
1,3,5-trichlorobenzene	1.0 ug/L
bis(2-ethylhexyl)phthalate	2.0 ug/L
pentachlorobenzene	1.2 ug/L
PAHs	
acenapthylene	1.0 ug/L
acenapthene	1.0 ug/L
2,4-dinitrotoluene	2.0 ug/L
9H fluorene	1.0 ug/L
phenanthrene	1.0 ug/L
anthracene	1.0 ug/L
fluoranthene	1.0 ug/L
chrysene	2.0 ug/L
benzo(a)anthracene	2.0 ug/L
benzo(a)pyrene	2.0 ug/L
benzo(k)fluoranthene	2.0 ug/L
benzo(b)fluoranthene	2.0 ug/L
dibenzo(ah)anthracene	2.0 ug/L
benzo(ghi)perylene	2.0 ug/L
indeno(123-cd)pyrene	2.0 ug/L
PCBs, Dioxins, Dibenzofurans	
PCB	0.1 ug/L
PCDF	0.2 - 2.5 ng/L
PCDD	0.5 - 2.5 ng/L

TABLE A1
PARAMETER LISTING AND DETECTION LIMITS
(continued)

Parameter	Detection Limit
PESTICIDES	
Chlorinated Pesticides	
beta-BHC	0.01 ug/L
gamma-chlordane	0.02 ug/L
alpha-chlordane	0.02 ug/L
aldrin	0.01 ug/L
mirex	0.05 ug/L
endosulfan sulfate	0.05 ug/L
endrin	0.015 ug/L
methoxychlor	0.02 ug/L
dieldrin	0.01 ug/L
alpha-BHC	0.01 ug/L
a-endosulfan-alpha	0.02 ug/L
gamma-BHC(lindane)	0.01 ug/L
endrin aldehyde	0.20 ug/L
toxaphene	0.20 ug/L
delta-BHC	0.01 ug/L
p,p-DDD	0.02 ug/L
o,p-DDT	0.02 ug/L
p,p-DDE	0.02 ug/L
oxychlordane	0.025 ug/L
heptachlor epoxide	0.015 ug/L
heptachlor	0.015 ug/L
p,p-DDT	0.02 ug/L
b-endosulfan-beta	0.02 ug/L
2,4-D	5.0 ug/L
silvex	5.0 ug/L
2,4,5-T	5.0 ug/L
N,P herbicides	
diazinon	0.5 ug/L
methylparathion	1.0 ug/L
parathion	5.0 ug/L
alachlor	0.015 ug/L

APPENDIX B
WATER USE AND WATER WELL SURVEY

- Contact Record
- Questionnaire

OWMC PHASE 4B

WATER USE AND WATER WELL STUDY

CONTACT RECORD

Interview No. :

Assessment Roll No. :

Interviewee :

Date	Time	Caller	Comments

General Comments

OWMC PHASE 4B

WATER USE AND WATER WELL STUDY

CONDUCTED BY

GARTNER LEE ASSOCIATES LIMITED

PROJECT 85 - GW - 1

AUGUST 1986

INTERVIEW # _____

QUESTION	RESPONSE

INTERVIEW INFORMATION

1 Name of the respondent? _____

2 Respondent's address? _____

_____

Ontario, _____ _____

Telephone no ( ) -

3 Interviewers name _____

4 Date of interview? (YY.MM.DD) _____

5 Time of interview? (military time) _____

LOCATION INFORMATION

6 Study Area?

1 = Site

2 = Adjacent

3 = Vicinity

4 = Access Roads

INTERVIEW # _____

QUESTION | RESPONSE

LAND OWNERSHIP INFORMATION

To be filled out for each block of assessed land

7 Assessment Roll Number? _____ | Owners Name & Address? _____

Lot ____ _____
Conc ____ _____
TWP ____ _____

Owners Telephone No. (____) ____-____ | Ontario, ___ ___

8 Assessment Roll Number? _____ | Owners Name & Address? _____

Lot ____ _____
Conc ____ _____
TWP ____ _____

Owners Telephone No. (____) ____-____ | Ontario, ___ ___

9 Assessment Roll Number? _____ | Owners Name & Address? _____

Lot ____ _____
Conc ____ _____
TWP ____ _____

Owners Telephone No. (____) ____-____ | Ontario, ___ ___

10 Assessment Roll Number? _____ | Owners Name & Address? _____

Lot ____ _____
Conc ____ _____
TWP ____ _____

Owners Telephone No. (____) ____-____ | Ontario, ___ ___

INTERVIEW # _____

QUESTION	RESPONSE

WATER USE INFORMATION

11 How many **water wells** are on this property ? (Mark their locations on the base map) _____

12 How many **oil or gas wells** are on this property ? (Mark their locations on the base map) _____

13 What is your source of **potable** or **drinking water**? _____

1 = Drilled well
2 = Hand dug well
3 = Bored well
4 = Cistern (truck water)
5 = Cistern (rain filled)
6 = River or stream
7 = Municipal supply
8 = Ponds
9 = Other _____

14 How many people use the drinking water at this property? _____

15 What is your source of **non-potable domestic water**? _____

1 = Not applicable
2 = Drilled well
3 = Dug or bored well
4 = Cistern (truck water)
5 = Cistern (rain filled)
6 = River or stream
7 = Municipal supply
8 = Ponds
9 = Other _____

16 What is your source(s) of **agricultural** water? _____

1 = Not applicable
2 = Drilled well
3 = Dug or bored well
4 = Cistern (truck water)
5 = Cistern (rain filled)
6 = River or stream
7 = Municipal supply
8 = Ponds
9 = Other _____

17 How many pigs use this water supply? _____

18 How many cattle use this water supply? _____

19 How many chickens use this water supply? _____

20 How many other animals are there on this property?

Type _____ Number _____
_____ _____
_____ _____

21 Do you use a septic tank and weeping field at this property? Y / N / N/A

INTERVIEW # _____

	QUESTION	RESPONSE
22	What is the distance between the weeping field and your drinking water well?	_____ (m)
23	Do you have an (agricultural) waste tank on this property?	Y / N / N/A
24	What is the distance between the waste tank and the drinking water well?	_____ (m)
25	Would you allow sampling of your well/cistern water for laboratory analysis at some later time?	Y / N / N/A

INTERVIEW # _____

QUESTION	RESPONSE

WELL INFORMATION

To be filled out for each well : water, gas/oil, active or not.

26 Type of well? _____
1 = Water well - domestic and drinking
2 = Water well - domestic nonpotable
3 = Water well - agricultural use
4 = Gas or oil well
9 = Other type _____

27 Does the well have an official identification number? (e.g. MOE water well number) _____

28 Where is the well located?
Lot? _____
Concession? _____
Township? _____
UTM Coordinates _____
(Mark the location on the base map)

29 What is the status of the well? _____
1 = In use 2 = Abandoned
3 = Planned for future use
4 = Unlikely to be used in the future

30 If not used, what is the reason? _____
1 = Insufficient QUANTITY
2 = Poor QUALITY
3 = Other reason _____

WELL CONSTRUCTION DETAILS

31 When was the well constructed? _____

32 Who installed it? _____

33 How was it installed? _____
1 = Drilled 2 = Bored or augered
3 = Dug by hand 4 = Dug by backhoe
5 = Other method _____

34 What is the casing DIAMETER? _____ (m)

35 What is the well DEPTH? _____ (m)

36 What is the elevation of the casing collar? _____ m a.s.l.

37 What was the original static water level? (metres below grade) _____ (m)

INTERVIEW # _____

	QUESTION	RESPONSE
38	What is the current static water level? (metres below grade)	_____ (m)
39	How is the top of the well finished? 1 = Casing above grade 2 = Casing at grade 3 = Casing below grade (in an open pit) 4 = Pump house over well 5 = Covered by concrete slab or housing (well pit) 6 = Well seal or pitless adaptor 7 = Open casing 8 = Plugged casing 9 = Casing pulled (open hole) 10 = Other	_____ _____
40	Is the well casing accessible (for sampling)?	Y /N
41	Is the well casing vented to the atmosphere?	Y / N
42	What type of pump is in the well? 1 = Submersible 2 = Deep well (jet pump) 3 = Shallow (jet pump) 4 = Hand pump 9 = Other	_____ _____
43	How old is the pump? When was it installed?	_____ _____
44	How is it lubricated? 1 = Oil 2 = Grease 3 = Water	_____
45	What is the depth of the pump intake?	_____ (m)
46	What is the pumping rate?	_____ (L/s gpm)

INTERVIEW # _____

QUESTION	RESPONSE

TANKS, TREATMENT AND TROUBLES

47 What type of permanent storage tank do you use? _____
1 = Galvanised steel 2 = Glass lined steel
3 = Plastic 4 = Concrete
5 = Concrete with plastic liner
9 = Other _____

48 What is the capacity of the storage tank? _____ litres gallons

49 Do you use a (a) Chlorinator? Y / N
(b) Water softener Y / N
(c) Filter Y / N
(d) Other water treatment Y / N _____

50 Is the treated water used for domestic or agricultural uses ? _____

51 What type of filter do you use? _____
1 = Sand 2 = Activated carbon
3 = Cartridge
9 = Other _____

52 Have you had any problems with this well? Y / N

53 What year did the problem occur? _____

54 What was the problem? _____
1 = Insufficient water 2 = Pump failure
3 = Plugging of the well 4 = Well interference
5 = Poor water quality 6 = Contamination
9 = Other _____

57 Has any government agency been notified about the problem? e.g. MOE _____

56 Has the problem been corrected? Y / N

58 How was it corrected? _____
1 = Well deepened 2 = Pump repaired
3 = New well constructed 4 = Water treatment
9 = Other _____

OWMC PHASE 4B
SURFACE DRAINAGE AND WATER USE SURVEY

WATER USE

1. How many streams, creeks and drainage swales are there on this property?

   (Please mark their locations and directions of flow on the base map.)

2. How many ponds are there on this property?

   (Please mark their locations on the base map.)

3. Do the animals on this property drink directly from the stream? Y / N

   Does the stream supply an adequate water supply for year-round use? Y / N

   If not ... do you know when and why the supply is inadequate?

4. Do the animals on this property drink directly from the pond? Y / N

   Does the pond supply an adequate water supply for year-round use? Y / N

   If not ... do you know when and why the supply is inadequate?

5. Do you irrigate from the streams and pond on this property? Y / N

   Is there an adequate water supply for your irrigation? Y / N

   If not ... do you know why the supply is inadequate?

SURFACE DRAINAGE AND FLOODING

Comment: Please ensure that the streams, creeks and drainage swales are marked on the base map, including the direction of flow.

6. What is the maximum depth of water flowing in the swales, creeks and ditches on this property?

   Are there any significant high water marks? Y / N
   Where and what are they?

   When were these observed (dates)?

   How many years have you been observing floods on this property?

7. Does flooding present a problem in the ditches and swales on your land?

   (Please mark the locations of the flooding on the base map.)

8. Are any of the flooding problems associated with buildings on your property?

   If so ... where, when and how frequently?

9. If you have flooding in the vicinity of your buildings, is this because of an overflow from a nearby stream or because of poor drainage in the vicinity of the building?

10. Do any of the local roads get flooded?

    (Please mark the locations on the base map.)

    What time of year does this flooding take place?
    How frequently does it take place?

11. Have any of the local bridges or culverts been improved or reconstructed in recent years?

    Where are they located on the base map?

SURFACE DRAINAGE AND FLOODING
(continued)

12. Does soil erosion present a problem on this property?

    If so ... where? Please mark the location on the base map.

    Have any conservation measures been taken to correct the erosion problems?

    If so ... what and where?

13. Do the streams flow all year round?
    Which ones dry up?
    How long are these streams dry?
    (say, how many weeks in the year)

14. Are crops normally grown through the field swales? Y / N

    Are there any places on the property where cropping is not possible because of poor drainage?

    If so ... where?

15. Have you ever consulted the Conservation Authority, the Ministry of the Environment, the Ministry of Natural Resources, the Ministry of Agriculture or any other government agency regarding flooding or soil erosion on this property?

    If so ... which agency, when and why?

16. What portion of this property is drained by tiles?

    Please mark the area on the map, showing the layout and the location of the outlet, if possible?

APPENDIX C

TABLE C1 - AGENCY CONTACTS

TABLE C1
AGENCY CONTACTS

Agency	Contact Person	Type of Contact C = Correspondence T = Telephone M = Meeting	Purpose of Contact/ Information Received
Niagara Peninsula Conservation Authority	T. Demario	T	- Criteria for storm water control
	D. Watson	T	- Datum for existing staff gauges at Beckett's bridge and Wellandport
	M. Miller	M	- General information on local water uses and concerns
Ministry of Natural Resources (Central Region)	L. Pataky	T	- General information on areas of responsibility and storm water policies
Ontario Hydro	J. Eaton	T,C	- Historical water level records for Niagara River and Chippawa Power Canal
			- Information regarding Hydro operations potentially affecting water levels in the Welland River
Environment Canada:			
- Water Survey of Canada	R. Mislek	T,C	- Streamflow data for Welland River and Twenty Mile Creek for 1985 and 1986
- Canadian Climate Centre	-	T	- Climatic Normals for Ontario (1951 - 1980) - Temperature and Precipitation
- Ontario Climate Centre	A. Radecki	T,C	- Climatological station reports for Welland and Vineland Station
- Atmospheric Environment Service	D. Carr	T	- Discussion regarding updating of Vineland Station I-D-F Analysis

TABLE C1

AGENCY CONTACTS

(continued)

Agency	Contact Person	Type of Contact C = Correspondence T = Telephone M = Meeting	Purpose of Contact/ Information Received
- Hamilton/Mount Hope Weather Office	-	T	- Precipitation updates and forecasts for scheduling of sampling episodes
- Inland Waters Directorate	M. Taylor	M	- Identification of areas of concern for impact assessment, water quality criteria and specific contaminants of concern in Welland River
- Waste Management Branch	J. Myslicky	M	- Identification of areas of concern for impact assessment, water quality criteria and specific contaminants of concern in Welland River
National Health and Welfare - Criteria Section	V. Armstrong A. Gilman	M	- Identification of areas of concern for impact assessment, water quality criteria and specific contaminants of concern in Welland River
International Joint Commission	J. MacDonald	T,M	- Background information and data sources based on IJC activities
Ministry of the Environment - Water Resources Branch . Aquatic Contaminants Section	D. Wells	M	- Water quality concerns, criteria and available information on Welland River

TABLE C1
AGENCY CONTACTS
(continued)

Agency	Contact Person	Type of Contact C = Correspondence T = Telephone M = Meeting	Purpose of Contact/ Information Received
. Waste and Water Management Section	Z. Novak	T	- Water quality concerns, criteria and available information on Welland River
- West Central Region	S. Irwin	M	- Water quality concerns, criteria and available information on Welland River water quality
Township of West Lincoln	M. Stratford	T,C	- Request for approval to erect staff gauges in Township rights-of-way
Regional Municipality of Niagara	R. Clegg	T	- Request for information on Region bench marks in Wellandport area
Ministry of Transportation and Communications	B. Burgin	T	- Request for information on MTC bench marks in Wellandport area

APPENDIX D
HYDROLOGIC MODELLING - SITE

APPENDIX D
HYDROLOGIC MODELLING-SITE
INTRODUCTION

The intent of this appendix is to fully describe the rationale and methodology used for estimating existing condition flows from the site.

The assessment and documentation of existing runoff patterns and quantities from the site provides a baseline against which post-development drainage patterns and quantities can be compared, and it also provides the standard to which mitigation must be considered (i.e. post-development flows reduced to pre-development levels, and/or no significant adverse impacts downstream as a result of development of the site).

In the following sections, existing site drainage is described and all existing storm water outlets from the site are identified. The modelling methodology is also described including the rationale for model and parameter selection. Alternate methods of flow computation are described, and where appropriate are used for comparison with results of the preferred model. An analysis is also carried out to determine if adjacent watercourses could potentially flood the site under extreme (heavy rainfall) conditions (see Appendix E).

EXISTING SITE DRAINAGE

The site is characterized by very little topographic relief (approximately 1.5 m from north to south) and is generally poorly drained. Drainage generally occurs in a north to south direction via very minor and ill-defined field swales. Some areas of the site are subject to local ponding during periods of snowmelt and wet weather.

The majority of the site area (70%) is drained by two swales which run the length of the site, outlet through two culverts beneath Vaughan Road and join together immediately downstream from Vaughan Road. From this point, runoff is conveyed directly south to the Welland River. This un-named creek is henceforth referred to as the 9C Creek.

The western portion of the site which drains to several local tributaries of Beaver Creek comprises approximately 26% of the total drainage area. These tributaries join together just south of Vaughan Road (southeast from the site) and eventually drain to the Welland River just upstream from the 9C Creek outlet described above.

The remaining 4% of the drainage area (extreme northeast corner of the site) drains via roadside ditches and shallow field swales to Sucker Creek, to the north and east of the site.

With the aid of available topographic mapping (1:2000 scale, 0.5 m contour interval) and detailed site surveys, nine locations were identified where runoff presently leaves the site. Seven of these are culvert outlets beneath roads adjacent to the site boundaries, while two are swales which cross the west site boundary. The outlets described above are shown on Figure 3.5.

In summary, under existing conditions, all site runoff drains to the Welland River via either the 9C Creek, Beaver Creek or Sucker Creek. All storm water outlets from the site (where runoff crosses site boundaries) have been identified and documented for further detailed analysis.

HYDROLOGIC ANALYSIS

GENERAL

Ideally, estimates of peak flow rates along a watercourse should be based upon historical streamflow data measured at several locations within the area under study, or on adjacent basins with similar characteristics. However, neither the site swales nor the creeks within adjacent basins have been gauged in the past and therefore no historical streamflow data is available for flow estimation purposes. To overcome this problem, hydrologic simulation procedures are generally used.

The HYMO computer model, since its development in the early 1970's by the U.S. Agricultural Research Service, has gained widespread use for flow calculation purposes in Ontario. In the absence of recorded flow data, it has been used for virtually all flood plain mapping studies in the Province over the last ten years. The application of the HYMO model to both undeveloped and developing areas has been improved recently by the IMPSWM group at the University of Ottawa (OTTHYMO). The HYMO/OTTHYMO model is ideal for assessing the impact that development may have on runoff volume and peak flows from a given area. Therefore this model has been selected for assessment of the impacts that the landfill development may have on runoff volumes and peak flows.

The model responds to a design storm (hyetograph) input by producing an estimate of the time-history of runoff (hydrograph) as output. In general, hydrographs can be developed at any location within the watershed. In the case of the Preferred Site, they can be developed at every storm water outlet from the site.

The program employs the U.S. Soil Conservation Service methodology of generating excess rainfall. The runoff hydrographs are developed on the basis of parameters which describe the physical characteristics of the drainage areas. These include soil type, land use, and area size, length and slope. The program is also capable of routing computed hydrographs through channels (variable storage coefficient method) and through reservoirs (storage-indication method).

The basic input data requirements for the model are:

i) a design storm hyetograph which defines the precipitation amount and pattern;

ii) basin parameters - curve number, drainage area, time to peak and initial abstraction;

iii) number of linear reservoirs (n) in the conceptual model;

iv) stage-storage-discharge data associated with various storage elements through which computed hydrographs will be routed.

DESIGN STORM SELECTION

General

The OTTHYMO hydrologic model requires a single rainfall event as input in order to generate a runoff hydrograph. Factors to be considered in the selection of this rainfall event include the following:

i) historical event (i.e. Hurricane Hazel) or return period storm (any of 1:5 year to 1:100 year);

ii) selection of recording rain gauge data;

iii) selection of rainfall distribution upon which to base the input hyetograph.

Rationale

For this study flow calculations were carried out for the 1:5, 1:10, 1:50 and 1:100 year storm events, as well as for the Regional Storm (Hurricane Hazel) as defined by the Ministry of Natural Resources. It is anticipated that the landfill drainage system components will be designed on the basis of the 1:100 year return period storm. Thus, it is considered prudent at this stage to calculate baseline condition flows for the same return period storm. Consideration was given to using Hurricane Hazel derived flows as a design basis. However, this event is considered too extreme for design of the landfill drainage facilities (ditches, culverts, storm water ponds, etc.). A Hurricane Hazel type of storm is generally used where failure of drainage facilities could result in catastrophic property damage and/or loss of life. Considering that the site is located in a predominantly rural area, and further, that failure of any of the drainage system components will not result in, or aggravate flooding problems downstream, acceptance of the 1:100 year return period design storm is considered appropriate.

In the selection of the most appropriate rainfall gauge upon which to base the design storm, consideration should be given to the following:

i) must be a continuous recording gauge;
ii) proximity to the site;
iii) number of years of record.

The Atmospheric Environment Service (AES) records and statistically analyzes rainfall data at several gauges which they maintain in the vicinity of the site. These gauges and pertinent data associated with each are listed in Table D1 and shown on Figure D1.

Column 2 in Table D1 above indicates whether the AES rainfall gauge at a given location is a continuous-recording (R) or non-recording (manually read) gauge. The continuous-recording gauges automatically record the volume of rainfall which has occurred at any point in time. Thus, the volume of rain which occurred even over a time interval as short as five minutes, can be obtained from a continuous-recording gauge by observing the strip chart for that gauge. Manually read or non-recording gauges generally provide a summary of rainfall volume which has occurred over a 12 or 24 hour period, depending on the frequency with which the local observer reads the gauge. In short, data from non-recording gauges is not useful in deriving the design storms necessary as input to the hydrologic model. They are simply listed in Table D1 to provide a complete listing of all AES rainfall gauges in the vicinity of the site.

The remaining six recording gauges have periods of record which range from 13 to 20 years. The short periods of record at all of the gauges suggest that none of the gauges can be ruled out on the basis of period of record alone. However, the Vineland Station gauge is closer to the site than the Port Colborne, Niagara Falls and Hamilton gauges and on this basis may be more representative of rainfall at the site. Since the St. Catharines gauge is slightly further from the site than the Vineland gauge and because it has a period of record shorter by three years, the Vineland gauge data was selected for development of the design storms. Furthermore, the Vineland Station gauge provides somewhat higher intensities for storms of short duration than the other gauges.

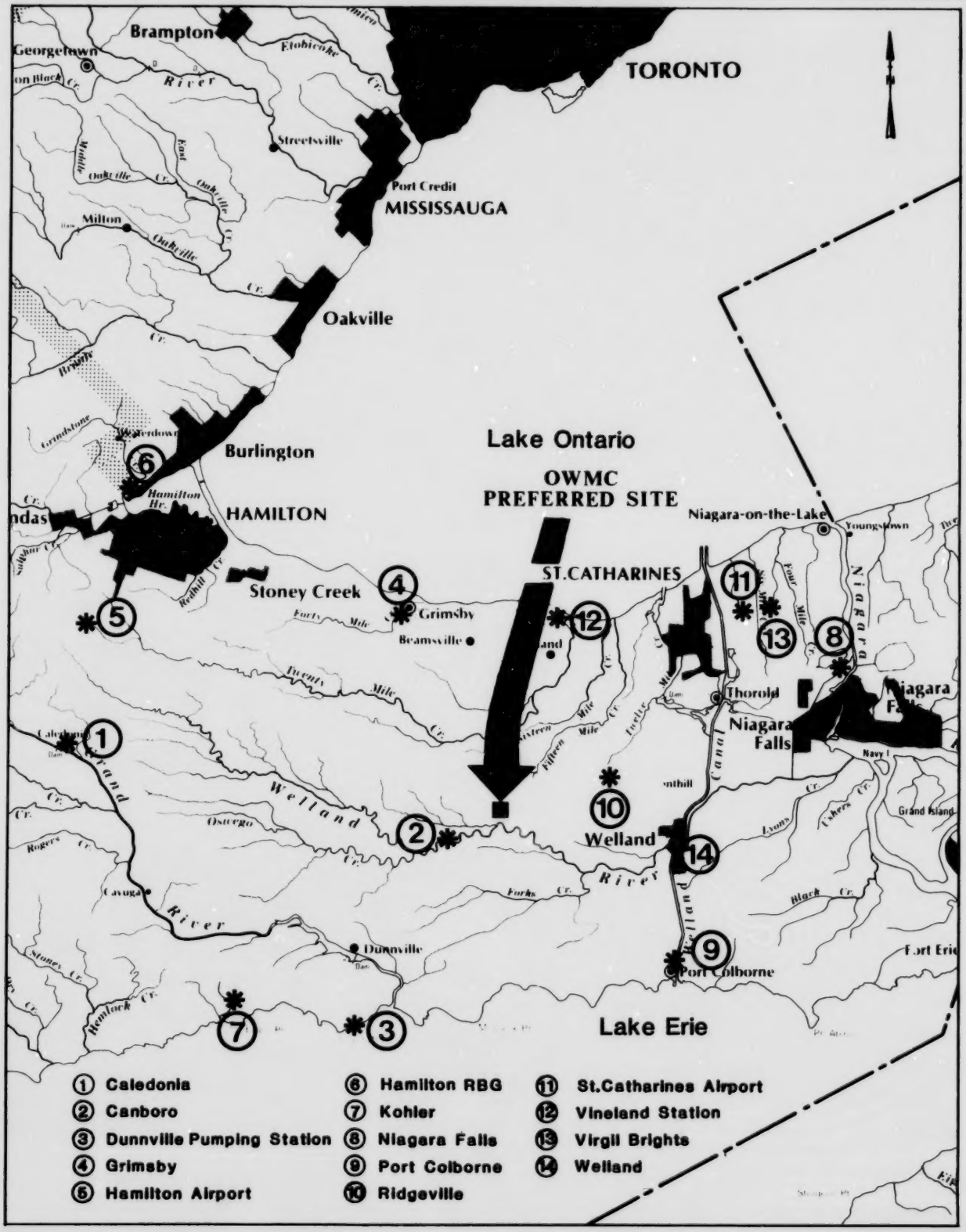
TABLE D1
RAINFALL GAUGES IN THE VICINITY OF SITE LF-9C

Location	Recording (R) or Non-Recording (NR)	Years of Record	Distance from Site
Caledonia (d)	NR	31	40.6 km
Canboro (d)	NR	23	10.0 km
Dunnville P.Stn.	NR	18	24.0 km
Grimsby	NR	52	19.2 km
Hamilton A	R	13	41.2 km
Hamilton RBG	R	19	44.6 km
Kohler (d)	NR	13	39.0 km
Niagara Falls	R	19	34.4 km
Port Colborne	R	20	23.0 km
Ridgeville	NR	13	10.5 km
St. Catharines A	R	13	28.6 km
Vineland Station	R	16	17.0 km
Virgil Brights (d)	NR	12	30.6 km
Welland	NR	86	15.0 km

NOTES: i) d = discontinued

ii) Years of record for non-recording gauges obtained from Canadian Climate Normals, Atmospheric Environment Service, 1982.

iii) Years of record for recording gauges obtained from Intensity - Duration - Frequency Values. Atmospheric Environment Service, 1984.



OWMC Ontario Waste Management Corporation

DILLON

10 0 10 20 Kilometres

CLIMATOLOGICAL STATION LOCATIONS

Figure D.1

To this point, the 1:100 year return period has been selected for design using rainfall data record at the AES Vineland Station gauge. It remains to select the design storm distribution. There are a number of general storm distributions currently in use. However, most are based on U.S. rainfall data or on data averaged over a large region and several gauges. For this study, the Keifer and Chu distribution was selected since it has the advantage that it is created directly from the local (Vineland Station) intensity-duration-frequency (IDF) data and not on the basis of composite or regional data. Therefore the rainfall intensities for each design storm (1:5 year to 1:100 year) will very closely follow the published AES IDF data.

The design storms utilized in the hydrologic model were of 24 hour duration and discretized in 10 minute intervals. The 24 hour duration was selected because it exceeds the maximum time of concentration of the areas under study and also because it is most appropriate in the examination of storage effects. The 10 minute discretization was selected to ensure the peaks of the smaller subwatershed hydrographs would not be missed. The sensitivity of peak flow estimates to a 5 minute discretization was also analyzed. However, there was no significant change in peak flow estimates and the limitations of the model only allow a 16 hour storm to be used with a 5 minute discretization. Therefore, the use of a 24 hour duration storm with 10 minute discretization interval is considered appropriate.

The design storm data described above is summarized below:

i) Rainfall Gauge - AES Vineland Station
ii) Distribution - Keifer and Chu
iii) Duration - 24 hours
iv) Discretization Interval - 10 minutes
v) Return Periods - 1:5, 1:10, 1:50, 1:100 year (for flow calculations)
vi) Return Period - 1:100 year (for design).

Rainfall data from the Vineland Station gauge which has been statistically analyzed by AES is given in Table D2. Of importance to the development of design hyetographs are the rainfall depths for selected frequencies and durations. Equations developed from the data which describe intensity as a function of duration are shown in Table D3. One equation is presented for each of the four return periods being analyzed. Finally the hyetographs developed on the basis of these equations by the method of Keifer and Chu are shown in Table D4.

BASIN PARAMETERS

The Preferred Site, as shown on Figure 3.5, was divided into seven subwatersheds for flow calculation purposes. These subwatersheds areas were developed to coincide with outlets where runoff crosses site boundaries. A description of the required hydrologic parameters required for modelling and their derivation is provided in the following.

i) Drainage Areas

The seven subwatershed areas shown on Figure 3.5, were developed using the 1:2000 scale, 0.5 m interval background mapping shown and supplemented with field surveys. In general, the subwatersheds indicate the extent of the catchment area contributing runoff to each outlet.

Subwatersheds 1, 2 and 3 contribute runoff from the western portion of the site to several tributaries of Beaver Creek. These tributaries outlet to Beaver Creek which eventually discharges to the Welland River approximately 2.5 km to the south. Subwatershed No. 1 comprises approximately 17.10 ha and discharges across the west site boundary via a shallow field swale. Subwatershed No. 2 comprises approximately 4.62 ha and also outlets from the site across the west site boundary. This outlet is located near the south end of the site adjacent to Vaughan Road. Subwatershed

TABLE D2

ATMOSPHERIC ENVIRONMENT SERVICE
SERVICE DE L'ENVIRONNEMENT ATMOSPHERIQUE

RAINFALL INTENSITY-DURATION FREQUENCY VALUES
INTENSITE, DUREE ET FREQUENCE DES PLUIES

PREPARED BY THE HYDROMETEOROLOGY DIVISION, CANADIAN CLIMMATE CENTRE (9/84)
PREPARE PAR LA DIVISION D'HYDROMETEOROLOGIE, CENTRE CLIMATOLOGIQUE CANADIEN (9/84)

****

VINELAND STATION ONT

****

LATITUDE 4311 LONGITUDE 7924 ELEVATION/ALTITUDE 79 M

RETURN PERIOD RAINFALL AMOUNTS (MM)
PERIODE DE RETOUR QUANTITES DES PLUIES (MM)

DURATION	2 YR/ANS	5 YR/ANS	10 YR/ANS	25 YR/ANS	50 YR/ANS	100 YR/ANS	YEARS OF RECORD ANNEES D'OBSERVATION
5 MIN	8.04	10.70	12.47	14.69	16.34	17.99	16
10 MIN	12.06	16.83	19.84	23.69	25.08	28.25	16
15 MIN	15.40	21.00	24.71	29.40	32.87	36.33	16
30 MIN	20.67	29.58	35.49	42.94	48.46	53.96	16
1 H	25.11	35.17	41.84	50.25	56.49	62.70	16
2 H	29.28	39.97	47.07	56.01	62.65	69.24	16
6 H	37.69	49.76	57.77	67.67	75.36	82.81	16
12 H	43.03	54.91	62.79	72.74	80.11	87.44	16
24 H	49.23	63.05	72.22	83.79	92.36	100.89	16

RETURN PERIOD RAIN EXPRESSED AS A RATIO OF ONE HOUR RAIN (2 YR RETURN PERIOD)

DURATION	2 YR/ANS	5 YR/ANS	10 YR/ANS	25 YR/ANS	50 YR/ANS	100 YR/ANS	YEARS OF RECORD ANNEES D'OBSERVATION
5 MIN	0.32	0.43	0.50	0.59	0.65	0.72	16
10 MIN	0.48	0.67	0.78	0.94	1.02	1.13	16
15 MIN	0.61	0.84	0.98	1.17	1.31	1.45	16
30 MIN	0.82	1.18	1.41	1.71	1.93	2.15	16
1 H	1.00	1.40	1.67	2.00	2.25	2.50	16
2 H	1.17	1.59	1.87	2.23	2.49	2.76	16
6 H	1.50	1.98	2.30	2.70	3.00	3.30	16
12 H	1.71	2.19	2.50	2.90	3.19	3.48	16
24 H	1.96	2.51	2.88	3.34	3.66	4.02	16

TABLE D3
VINELAND STATION RAINFALL GAUGE
CHARACTERISTIC EQUATIONS FOR
INTENSITY-DURATION-FREQUENCY CURVES

Return Period Years	Equation
5	$i = \dfrac{1435.50}{(t + 11)^{0.8698}}$
10	$i = \dfrac{1824.17}{(t + 11.8)^{0.8848}}$
50	$i = \dfrac{2866.71}{(t + 13.8)^{0.9144}}$
100	$i = \dfrac{3248.10}{(t + 14.1)^{0.9101}}$

i = intensity (mm/h)

t = duration (minutes)

TABLE D4

HYETOGRAPHS FOR SPECIFIED RETURN PERIOD

(KEIFER AND CHU METHOD BASED ON VINELAND STATION DATA)

TIME (Hours-Minutes)	INCREMENTAL RAINFALL INTENSITY (mm/hour)			
	5-Year	10-Year	50-Year	100-Year
0:0	0.0	0.0	0.0	0.0
0:10	0.4	0.4	0.4	0.4
0:20	0.4	0.4	0.4	0.4
0:30	0.4	0.4	0.4	0.4
0:40	0.4	0.4	0.4	0.4
0:50	0.4	0.4	0.4	0.4
1:00	0.4	0.4	0.4	0.4
1:10	0.4	0.4	0.4	0.4
1:20	0.4	0.4	0.4	0.4
1:30	0.4	0.4	0.4	0.4
1:40	0.4	0.4	0.4	0.4
1:50	0.4	0.4	0.4	0.4
2:00	0.4	0.4	0.4	0.4
2:10	0.4	0.4	0.4	0.4
2:20	0.4	0.4	0.4	0.4
2:30	0.4	0.4	0.4	0.5
2:40	0.4	0.4	0.4	0.5
2:50	0.4	0.5	0.4	0.5
3:00	0.4	0.5	0.5	0.5
3:10	0.5	0.5	0.5	0.5
3:20	0.5	0.5	0.5	0.5
3:30	0.5	0.5	0.5	0.5
3:40	0.5	0.5	0.5	0.5
3:50	0.5	0.5	0.5	0.5
4:00	0.5	0.5	0.5	0.5
4:10	0.5	0.5	0.5	0.5
4:20	0.5	0.5	0.5	0.6
4:30	0.5	0.5	0.5	0.6
4:40	0.5	0.6	0.6	0.6
4:50	0.6	0.6	0.6	0.6
5:00	0.6	0.6	0.6	0.6
5:10	0.6	0.6	0.6	0.6
5:20	0.6	0.6	0.6	0.6
5:30	0.6	0.6	0.6	0.7
5:40	0.6	0.6	0.6	0.7
5:50	0.6	0.7	0.7	0.7
6:00	0.6	0.7	0.7	0.7
6:10	0.7	0.7	0.7	0.7
6:20	0.7	0.7	0.7	0.8
6:30	0.7	0.7	0.8	0.8
6:40	0.7	0.8	0.8	0.8
6:50	0.7	0.8	0.8	0.8
7:00	0.8	0.8	0.8	0.9
7:10	0.8	0.8	0.9	0.9
7:20	0.8	0.9	0.9	0.9
7:30	0.8	0.9	0.9	1.0
7:40	0.9	0.9	1.0	1.0
7:50	0.9	1.0	1.0	1.1
8:00	0.9	1.0	1.1	1.1
8:10	1.0	1.0	1.2	1.2
8:20	1.0	1.1	1.2	1.2
8:30	1.1	1.1	1.3	1.3
8:40	1.1	1.2	1.3	1.4
8:50	1.2	1.2	1.4	1.4
9:00	1.2	1.3	1.5	1.5
9:10	1.3	1.4	1.6	1.6
9:20	1.4	1.5	1.7	1.7
9:30	1.5	1.6	1.9	1.9
9:40	1.6	1.7	2.0	2.0
9:50	1.7	1.8	2.2	2.2
10:00	1.8	2.0	2.5	2.4
10:10	2.0	2.2	2.7	2.6
10:20	2.2	2.4	3.1	2.9
10:30	2.4	2.6	3.5	3.3
10:40	2.7	3.0	4.1	3.8
10:50	3.1	3.4	4.8	4.4

TABLE D4
HYETOGRAPHS FOR SPECIFIED RETURN PERIOD
(KEIFER AND CHU METHOD BASED ON VINELAND STATION DATA)
(continued)

TIME (Hours-Minutes)	INCREMENTAL RAINFALL INTENSITY (mm/hour) 5-Year	10-Year	50-Year	100-Year
11:00	3.5	4.0	5.9	5.2
11:10	4.2	4.7	7.5	6.4
11:20	5.2	5.9	10.0	8.2
11:30	6.7	7.7	14.6	11.0
11:40	9.4	11.0	24.6	16.1
11:50	15.3	18.0	56.7	27.3
12:00	34.4	41.0	158.0	62.9
12:10	101.6	119.3	56.7	174.4
12:20	34.4	41.0	24.6	62.9
12:30	15.3	18.0	14.6	27.3
12:40	9.4	11.0	10.0	16.1
12:50	6.7	7.7	7.5	11.0
13:00	5.2	5.9	5.9	8.2
13:10	4.2	4.7	4.8	6.4
13:20	3.5	4.0	4.1	5.2
13:30	3.1	3.4	3.5	4.4
13:40	2.7	3.0	3.1	3.8
13:50	2.4	2.6	2.7	3.3
14:00	2.2	2.4	2.5	2.9
14:10	2.0	2.1	2.2	2.6
14:20	1.8	2.0	2.0	2.4
14:30	1.7	1.8	1.9	2.2
14:40	1.6	1.7	1.7	2.0
14:50	1.5	1.6	1.6	1.9
15:00	1.4	1.5	1.5	1.7
15:10	1.3	1.4	1.4	1.6
15:20	1.2	1.3	1.3	1.5
15:30	1.2	1.2	1.3	1.4
15:40	1.1	1.2	1.2	1.4
15:50	1.1	1.1	1.2	1.3
16:00	1.0	1.1	1.1	1.2
16:10	1.0	1.0	1.0	1.2
16:20	0.9	1.0	1.0	1.1
16:30	0.9	1.0	1.0	1.1
16:40	0.9	0.9	0.9	1.0
16:50	0.8	0.9	0.9	1.0
17:00	0.8	0.9	0.9	0.9
17:10	0.8	0.8	0.8	0.9
17:20	0.8	0.8	0.8	0.9
17:30	0.7	0.8	0.8	0.8
17:40	0.7	0.8	0.8	0.8
17:50	0.7	0.7	[illegible]	0.8
18:00	0.7	0.7	0.7	0.8
18:10	0.7	0.7	0.7	0.7
18:20	0.6	0.7	0.7	0.7
18:30	0.6	0.7	0.6	0.7
18:40	0.6	0.6	0.6	0.7
18:50	0.6	0.6	0.6	0.7
19:00	0.6	0.6	0.6	0.6
19:10	0.6	0.6	0.6	0.6
19:20	0.6	0.6	0.6	0.6
19:30	0.6	0.6	0.6	0.6
19:40	0.5	0.6	0.5	0.6
19:50	0.5	0.5	0.5	0.6
20:00	0.5	0.5	0.5	0.6
20:10	0.5	0.5	0.5	0.5
20:20	0.5	0.5	0.5	0.5
20:30	0.5	0.5	0.5	0.5
20:40	0.5	0.5	0.5	0.5
20:50	0.5	0.5	0.5	0.5
21:00	0.5	0.5	0.5	0.5
21:10	0.5	0.5	0.5	0.5
21:20	0.4	0.5	0.4	0.5
21:30	0.4	0.5	0.4	0.5
21:40	0.4	0.4	0.4	0.5
21:50	0.4	0.4	0.4	0.5
22:00	0.4	0.4	0.4	0.4
22:10	0.4	0.4	0.4	0.4
22:20	0.4	0.4	0.4	0.4
22:30	0.4	0.4	0.4	0.4
22:40	0.4	0.4	0.4	0.4
22:50	0.4	0.4	0.4	0.4
23:00	0.4	0.4	0.4	0.4
23:10	0.4	0.4	0.4	0.4
23:20	0.4	0.4	0.4	0.4
23:30	0.4	0.4	0.4	0.4
23:40	0.4	0.4	0.4	0.4
23:50	0.4	0.4	0.4	0.4
24:00	0.3	0.4	0.4	0.4
24:10	0.3	0.4	0.4	0.4

No. 3 comprises an area of approximately 14.18 ha, and drains from north to south to Vaughan Road. This area actually has three culvert outlets from the site beneath Vaughan Road. All are very small diameter (0.3 - 0.4 m Ø) corrugated steel pipes (CSP). For computation purposes, they have been treated as a single outlet since:

a) the swales to which they drain join a common tributary of Beaver Creek immediately downstream from Vaughan Road;

b) ponding to a given elevation upstream from any one of these culverts would result in ponding to the same elevation upstream from the other two as a result of a hydraulic connection between them.

Subwatersheds No. 4 and 5 drain the central and eastern portions of the site beneath Vaughan Road to the 9C Creek as shown on Figure 3.5. This swale discharges directly to the Welland River approximately 2.0 km downstream. Subwatershed No. 4 drains an area of 31.14 ha and discharges from the site through a 0.6 m Ø CSP beneath Vaughan Road. Subwatershed No. 5 comprises an area of 61.49 ha including very small external areas to the west (0.68 ha), north (3.51 ha) and east (3.00 ha) of the site. This area has its outlet from the site via a 0.6 m Ø CSP beneath Vaughan Road.

Subwatersheds No. 6 and 7 contribute runoff from the extreme northeast corner of the site to separate tributaries of Sucker Creek. Sucker Creek discharges directly to the Welland River approximately 3.0 km to the south of the site. In detail, Subwatershed No. 6 comprises an area of 3.77 ha and discharges from the site via a 0.3 m Ø CSP beneath Schram Road. Subwatershed No. 7 comprises an area of 2.00 ha and discharges from the site via a 0.8 m Ø CSP beneath Highway 20.

In summary, the site has been divided into seven sub-watersheds for hydrologic modelling purposes. Each subwatershed contributes runoff to one storm water outlet (either a swale or culvert) except Sub-watershed No. 3 which contributes runoff to three small culverts along Vaughan Road.

Subwatersheds 1, 2 and 3 drain to various tributaries of Beaver Creek, Subwatersheds 4 and 5 drain to the 9C Creek and Subwatersheds 6 and 7 drain to Sucker Creek. All three of these watercourses ultimately discharge to the Welland River approximately 2-3 km south of the site.

ii) Curve Number (CN)

The curve number is an indicator of the runoff potential from an area and is used to determine what percentage of rainfall actually becomes runoff for a given event. The CN value incorporates information on soil type, land use and antecedent moisture condition as described below. Values for this parameter can vary from 0 to 100 with the quantity of runoff increasing with increasing CN values.

All soil types in Ontario which are identified on Agricultural Soil Maps have been assigned to one of four main hydrologic soil groups, which reflect their runoff producing capabilities. The "A" grouping represents well drained soils (sands and gravels) having high infiltration and transmission capabilities and low runoff potential. The "D" grouping describes heavy clay soils which retard infiltration and transmission of water, and hence exhibit high runoff potential. The B and C groups define soils with runoff characteristics between the two extremes.

Land use also plays a significant role in determining the quantity of runoff generated. The greater the ability of a given land use to prevent rainfall from becoming surface runoff, the lower the total runoff volume. Clearly a highly forested area will yield lower runoff than a pasture given the same rainfall input.

The antecedent moisture condition of a soil is based on the amount of rainfall which occurred in the five days preceding a storm event. There are three standard antecedent moisture conditions reflecting dry, average and saturated ground conditions. For general hydrologic analyses using return period storms, an average antecedent moisture condition (AMC II) is normally assumed.

On the basis of the general description above, the curve number used in modelling runoff from the site was selected as follows:

i) Soil Type - Haldimand Clay Loam (Soil Survey of Lincoln County, Canada Department of Agriculture, 1963) on-site and in the site vicinity.

ii) Hydrologic Soil Grouping = C (see Table D5).

iii) Land Use - assume "fair" pasture conditions.

iv) Antecedent Moisture Condition - average (AMC II) used for normal design conditions.

v) Curve Number = 79 (see Table D6).

TABLE D5

HYDROLOGIC SOIL GROUPS

Soils Series	Soil Texture	Hyd. Soil Grp.	Soils Series	Soil Texture	Hyd. Soil Grp.	Soils Series	Soil Texture	Hyd. Soil Grp.
Darlington	s	B	"	c l	C	Heidelburg	f s l	B
"	l	C	Ferndale	si l	BC	Hendrie	s /g	AB
Dawson	s l	A	"	c l	C	Henwood	s /g	A
"	l	B	Flamboro	s	B	Hespeler	s l	B
Deloro	l	B	"	s l	B	Hillier	c &c l	C
Devlin	si c /	C	Floradale	l	B	Hillsburgh	s l	A
	c l		Fonthill	g	A	Himsworth	si l	BC
Dinorwic	c	BC	"	l	B	Hinchinbr.	s l	B
Dobie	c /l	BC	Font	g s l	A	"	l	BC
Doe	s l	B	Forbes	c	D	"	si l	BC
"	si l	BC	Fox	s	A	Honeywood	s l	AB
Donald	l	B	"	s l	AB	"	si l	BC
Donnybrook	s g	A	"	gr l	AB	"	s	A
"	s l	AB	Foxboro	s	A	Howland	s l	B
"	l	B	Franktown	l	B	"	l	BC
Dorion	c /l	C	Freeport	s l	B	Huron	s l	B
Dorking	si c l	BC	Galesburg	s l	A	"	l	BC
Dumfries	s l	A	"	l	AB	"	si l	BC
"	l	AB	Gameland	s /g	AB	"	c l	CorD
Dummer	s l	A	Gananoque	c	C	"	c	D
"	l	B	Gerow	c l	C	Innisville	s l	B
Dundonald	s l	AB	Gilford	s l	B	Jeddo	l	BC
Dunedin	c	D	"	l	B	"	c l	C
Dymond	s l	AB	Gordon	si c	C	"	c	D
"	l	B	Granby	s	B	Kanawong	si l	BC
Eagle Lake	s /g	AB	"	s l	B	Kars	s /g	A
Eamer	l	BC	Grand	l	B	"	s l	B
Earlton	si l	B	Grenville	s l	A	Kemble	si l	BC
"	c l	C	"	l	BC	"	si c l	C
Eastport	s	A	Grimsby	s l	A	"	si c	C
Edenvale	s	AB	Guelph	s l	A	"	l	D
"	s l	B	"	l	BC	Kenabeek	s	B
Eganville	l	B	"	si l	BC	"	s l	B
Elderslie	si l	BC	Guerin	s l	AB	Killean	l /s l	AB
"	si c l	C	"	l	B	King	si l	BC
"	c l	C	Gwillimb.	g	AB	"	c l	C
Eldorado	s l	A	Haileybury	si c l	C	Kirkland	s l	A
"	l	B	"	si c	C	Kessith	s l	B
Elk Pit	s g	A	"	c	CD	L'Achigan	s	AB
Ellwood	c l	C	Haldimand	si l	BC	Lambton	l	BC
Elmbrook	si l	BC	"	si c l	C	"	si l	BC
"	c l	C	"	c	CorD	Lanark	c	C
"	c	C	"	c l	C	Lansdowne	c /si l	C
Elmira	l	B	Hanbury	si c l	C	Leech	si c l	C
Elmsley	s l	B	"	si c	C	"	c l	D
Embro	s l	BC	"	c	D	Leitrim	g	B
"	si l	C	Harkaway	l	B	Leith	si l	BC
Emily	l	B	"	si l	BC	Lily	l /s l	B
Emo	c & p	C	Harriston	l	BC	Lincoln	si c	C
Englehart	s l	B	"	si l	BC	"	c	C
Evanturel	si l	BC	Harrow	s	A	Lindsay	c l	C
"	si c l	C	"	s l	AB	"	c	C
Falardeau	si l	BC	"	l	B	Lisbon	s l	A
"	si c l	C	Havelock	s /g	A	Listowel	l	B/BC
Farmington	s l	A	Hawkesvi.	l	B	"	si l	BC
"	l	B	Haysville	s l	AB	Little Cur.	c	C

Source: MTC Drainage Manual, Volume 2, 1984.

TABLE D6

RUNOFF CURVE NUMBERS FOR HYDROLOGIC SOIL COVER COMPLEXES

(Antecedent moisture condition II, and $I_a = 0.2\ S$)

Land use	Cover: Treatment or practice	Cover: Hydrologic condition	Hydrologic soil group A	B	C	D
Fallow	Straight row	----	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	"and terraced	Poor	66	74	80	82
	" " "	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	"and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes 1/ or rotation meadow	Straight row	Poor	66	77	85	89
	" "	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
	"and terraced	Poor	63	73	80	83
	"and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	"	Fair	25	59	75	83
	"	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		----	59	74	82	86
Roads (dirt) 2/		----	72	82	87	89
(hard surface) 2/		---	74	84	90	92

1/ Close-drilled or broadcast.
2/ Including right-of-way.

Source: U.S. SCS National Engineering Handbook - Section 4, Hydrology, 1985

iii) Time to Peak (Tp)

The estimation of time to peak for each of the subwatersheds was a two step process, first requiring the estimation of time of concentration (Tc) then converting to time to peak using the equation:

$$Tp = 0.6\ Tc + \frac{D}{2}$$ (1)

where Tp = time to peak (hours)

Tc = time of concentration (hours)

D = rainfall increment (hours)

Time of concentration is defined as the time of travel from the hydraulically most distant point in the watershed to the watershed outlet. There are numerous methods available for estimating the time of concentration for a watershed (see Table D7). Unfortunately they often yield widely varying results and judgement is required for an appropriate estimate. Subwatershed Tc estimates based on five methods are shown in Table D8.

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(1) U.S. Soil Conservation Service, 1985.

TABLE D7
SUMMARY OF METHODS USED FOR Tc ESTIMATION

Method	Equation	Parameter Description	Comments
Bransby Williams(1)	$Tc = \frac{.057L}{S^{0.2} A^{0.1} 60}$	L = watershed length (m) S = watershed slope (%) A = watershed area (ha)	- Generally used for small culvert design - underestimates Tc in permeable basins
Curve No. Method(2)	$Tc = \frac{L^{0.8} (S+1)^{0.7}}{1900 Y^{0.5} 0.6}$	L = watershed length (ft.) S = 1000/CN-10 (CN = Curve No.) Y = watershed slope (%)	- applicable to small watersheds (less than 800 hectares) - generally tends to overestimate Tc
Airport Formula(1)	$Tc = \frac{3.26(1.1-C)L^{0.5}}{S^{0.33} 60}$	C = runoff coefficient L = watershed length (m) S = watershed slope (%)	- generally used for permeable areas - developed for airfield drainage systems
Kirpich Formula(3)	$Tc = \left[\frac{11.9L^3}{H} \right]^{0.385}$	L = length (miles) H = elevation difference (ft)	- developed for steep-sloped, hilly areas - tends to underestimate Tc in general
Upland Method(2)	see Figure D2		- applicable to small watersheds (<800 hectares) - useful when flow does not occur in well defined channels

(1) Drainage Manual, Ontario Ministry of Transportation and Communications, Volume 2, 1984.

(2) National Engineering Handbook- Section 4, Hydrology - Soil Conservation Service, Washington, D.C., March 1985.

(3) Design of Small Dams, U.S. Dept. of the Interior, Bureau of Reclamation, 1977.

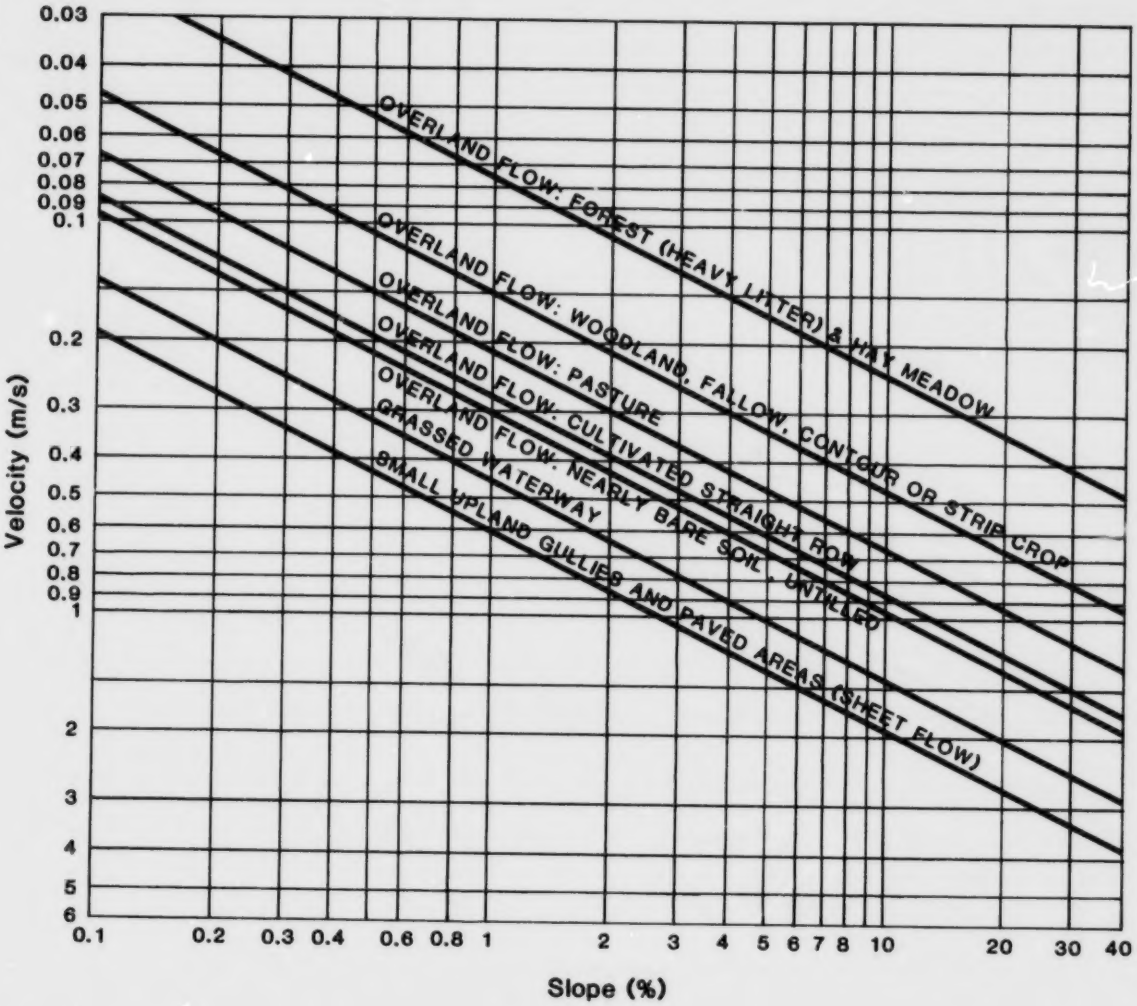
TABLE D8
TIME OF CONCENTRATION ESTIMATES USING VARIOUS METHODS

Subwatershed	Bransby-Williams	Curve Number	Airport Formula	Kirpich	Uplands (Grassed Waterway)
1	52 (0.9)	234 (3.9)	142 (2.4)	50 (0.8)	86 (1.4)
2	25 (0.4)	90 (1.5)	78 (1.3)	21 (0.4)	32 (0.5)
3	37 (0.6)	120 (2.0)	92 (1.5)	28 (0.5)	47 (0.8)
4	74 (1.2)	257 (4.3)	149 (2.5)	57 (1.0)	116 (1.9)
5	118 (2.0)	549 (9.2)	206 (3.4)	109 (1.8)	207 (3.5)
6	20 (0.3)	68 (1.13)	64 (1.1)	18 (0.3)	23 (0.4)
7	10 (0.2)	13 (0.2)	23 (0.4)	10 (0.2)	10 (0.2)

Note: Top line is minutes, bracketted figure below is hours.

Observation of results in Table D8 indicates that the Curve Number Method yields longer Tc estimates than any other method for every subwatershed except No. 7. The 9.2 hour estimate for subwatershed No. 5 is considered excessive for a 61 ha area. Therefore, this method can be ruled out on the basis that its Tc estimates are too long, practically, and in comparison to all of the other methods. Conversely, the Kirpich method yielded the shortest Tc's of any of the methods for every subwatershed. This could be expected since it was developed for steeper sloping watersheds. Up until several years ago, this method was widely used for estimating Tc's in Southern Ontario. However, it has since fallen into disuse because of its tendency toward underestimation of Tc and hence overestimation of flows. Therefore, the Kirpich method and the Bransby-Williams method (which yields results almost identical to Kirpich) can both be eliminated on the basis that Tc's are underestimated. Thus it remains to choose between the Airport Method and the Uplands Method. The Airport Method yields Tc values which are approximately twice those given by the Uplands Method. The long Tc's provided by the Airport Formula likely occur because it was developed for permeable areas. This formula may not have application to the Preferred Site since it is considered relatively impermeable based on its heavy clay soils. By comparison, the Uplands Method was developed for small drainage areas at the upper end of a watershed where there are no well defined creeks or channels. Thus, this method is ideally suited to estimating Tc's from the Preferred Site. Further, estimated flow velocities of 0.15 to 0.24 m/s (0.5 to 0.8 fps) seem appropriate for the very mild sloping (.05 to .25%) subwatersheds. (Velocity estimates are based on the grassed waterway curve shown on Figure D2).

In summary, numerous methods were examined for estimating times of concentration for the individual subwatersheds. The Uplands Method was selected as the most appropriate. The time of concentration values obtained by the Uplands Method were converted



SOURCE: NATIONAL ENGINEERING HANDBOOK,
U.S. SOIL CONSERVATION SERVICE, 1985

OWMC Ontario Waste Management Corporation

DILLON

UPLAND METHOD FOR ESTIMATING TIME OF CONCENTRATION

Figure D2

to time to peak values (required as input by the model) using the relation Tp = .6 Tc + D/2 (see previous description of parameters).

iv) Initial Abstraction

Initial Abstraction represents the rainfall volume at the outset of a storm which is taken up by wetting of the ground cover, and through filling of depression storage. Recent research (University of Ottawa, 1983) indicates that in general, this value should be in the 1 to 5 mm range (per unit area). However, topographic mapping and site observations indicate that initial abstraction is likely far greater than the 1 to 5 mm values generally applied. From site mapping, low lying, poorly drained areas were estimated to comprise approximately 20% of the site area. The assumption of a 76 mm (3 inch) depth of storage in these low lying areas results in an average initial abstraction value of 15 mm over the entire site. This 15 mm value was used as input for each of the subwatersheds.

v) Other Input Data

The final input parameter required in the calculation of runoff hydrographs is the number of linear reservoirs "n" in the conceptual model. This parameter relates to the "peakiness" of the computed hydrograph, with higher "n" values producing a steeper, higher peaked hydrograph. The IMPSWM Manual (University of Ottawa, 1983) indicates that "n" generally falls into the range from 2 to 6, with 3 being a reasonable default value in the absence of recorded data. Accordingly, an "n" value of 3 has been selected for all subwatersheds. For a more complete description of the theory associated with this parameter, the reader is referred to the IMPSWM Manual (University of Ottawa, 1983).

In summary, basin parameters described under items i) to v) above are summarized in Table D9.

TABLE D9
SUBWATERSHED PARAMETERS

Sub-Watershed Number	Area (ha)	Runoff Curve No.	Time to Peak (hours)	Initial Abstraction (mm)
1	17.10	79	0.86	15
2	4.62	79	0.32	15
3	14.18	79	0.47	15
4	31.14	79	1.16	15
5	61.49	79	2.07	15
6	3.77	79	0.23	15
7	2.00	79	0.20	15

HYDROGRAPH ROUTING

Subwatershed areas were delineated such that individual hydrographs would be developed at each existing storm water outlet from the site. This made the modelling exercise relatively simple since complications associated with computing, routing and adding intermediate hydrographs together were avoided. However, it was noted, particularly for Subwatersheds 3, 4, 5 and 6, that limited capacity of the outlet culverts could cause temporary back-up of

water onto the site. This temporary on-site storage of runoff could potentially decrease peak flows downstream, depending on the amount of storage volume available upstream from the culvert outlets prior to overtopping the road.

To assess the impact that this on-site storage would have on peak flows outletting from the site, reservoir routing of the hydrographs computed from Subwatersheds 3, 4, 5 and 6 was carried out. Reservoir routing of the hydrographs from Subwatersheds 1 and 2 was not carried out since they outlet from the site via overland flow swales, and not through limited capacity culverts. Therefore, there is no artificially induced on-site storage through which to route at these two locations. Although Subwatershed 7 has a culvert outlet, it is of sufficient size relative to the peak flow rate and available upstream storage volume that reservoir routing would not significantly affect the peak outflow. Therefore, reservoir routing was not carried out at this location.

The procedure for routing the hydrographs from Subwatersheds 3, 4, 5, and 6 is described below.

i) Subwatershed No. 3

Runoff from Subwatershed No. 3 outlets from the site via 2-0.3 m Ø CSP and 1-0.4 m Ø CSP as shown on Figure 3.5. If the capacity of these culverts is exceeded, flow would overtop Vaughan Road. For the purposes of reservoir routing, these three culvert outlets were assumed to be a single outlet. This is appropriate because of the hydraulic connection between them (i.e. ponding upstream from any one of of these culverts will result in ponding to the same level at the other two). Modelling the impact of storage on peak flows requires development of a stage-storage-discharge relationship for the outlet. The storage volume available at various stages was obtained by measuring the area enclosed by the appropriate contours (1:2000 scale, 0.5 m contour interval

topographic mapping) and assuming an average depth. The stage-discharge relationship was obtained for each of the culvert outlets using standard inlet control nomographs (U.S. Bureau of Public Roads, 1965). Weir flow over Vaughan Road was estimated using the equation -

$$Q = CLH^{1.5}$$

where Q = flowrate (m^3/s)
L = Weir length (m)
H - head on Weir (m)
C = Weir coefficient (1.66).

The top of road profile and culvert inverts were obtained from field survey data. The outlet rating curve from Subwatershed No. 3 is given in Table D10.

ii) Subwatershed Nos. 4, 5 and 6:

Unlike Subwatershed No. 3 which has three culvert outlets, Subwatershed Nos. 4, 5 and 6 have only one outlet each (0.6 m Ø, 0.6 m Ø and 0.3 m Ø CSP's respectively). Otherwise the development of the stage-storage-discharge relationship for each outlet is exactly the same as described for Subwatershed No. 3 above.

The rating curves for Subwatershed Nos. 4, 5 and 6 are given in Tables D11, D12 and D13 respectively.

TABLE D10
SUBWATERSHED NO. 3 RESERVOIR ROUTING
ELEVATION-DISCHARGE-STORAGE RELATIONSHIP

Elevation (m)	Discharge (m^3/s)	Storage (ha-m)
183.1	0.00	0.00
183.4	0.16	0.14
183.5	0.26	0.20
183.6	0.33	0.28
183.7	0.38	0.42
183.8 (Top of Road)	0.43	0.60
183.9	3.00	0.82

TABLE D11
SUBWATERSHED NO. 4 RESERVOIR ROUTING
ELEVATION-DISCHARGE-STORAGE RELATIONSHIP

Elevation (m)	Discharge (m^3/s)	Storage (ha-m)
182.65	0.00	0.00
183.00	0.20	0.10
183.50	0.34	0.40
183.40	0.45	0.65
183.50	0.50	0.96
183.65 (Top of Road)	0.60	1.50
183.70	2.00	1.80

TABLE D12
SUBWATERSHED NO. 5 RESERVOIR ROUTING
ELEVATION-DISCHARGE-STORAGE RELATIONSHIP

Elevation (m)	Discharge (m^3/s)	Storage (ha-m)
182.65	0.00	0.00
183.00	0.20	0.10
183.25	0.34	0.30
183.40	0.45	0.60
183.50	0.50	0.94
183.60 (Top of Road)	0.57	1.50
183.70	2.60	2.00

TABLE D13
SUBWATERSHED NO. 6 RESERVOIR ROUTING
ELEVATION-DISCHARGE-STORAGE RELATIONSHIP

Elevation (m)	Discharge (m^3/s)	Storage (ha-m)
184.3	0.00	0.00
184.5	0.03	0.03
184.6	0.06	0.06
184.7	0.09	0.12
184.8 (Top of Road)	0.10	0.20

HYDROLOGIC MODEL

On the basis of the input parameters described above, the OTTHYMO model shown in Figure D3 was developed. This model generates runoff hydrographs at each of the seven storm water outlets from the site.

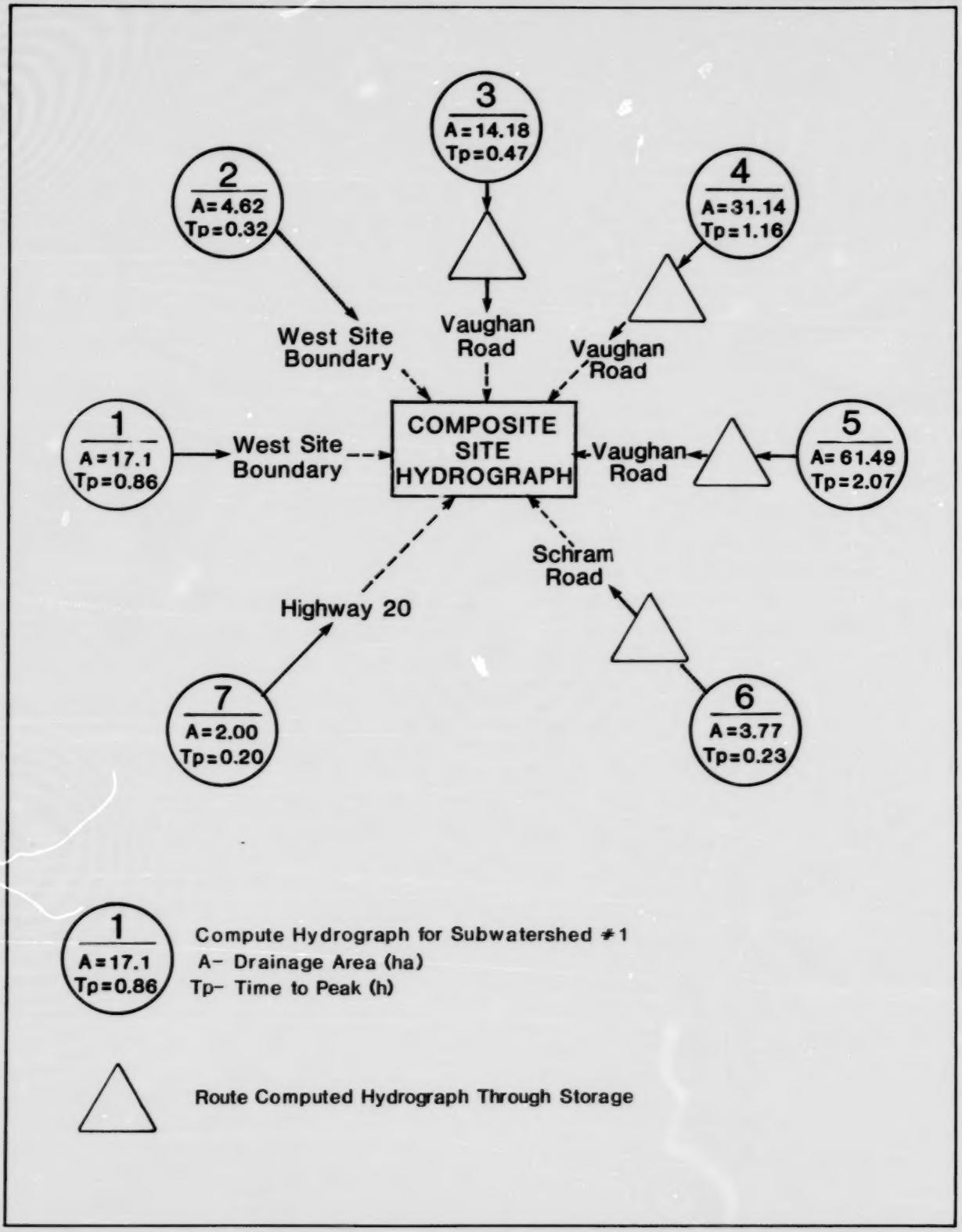
The circles shown on Figure D3 represent the computation of individual subwatershed hydrographs. Within each circle, the subwatershed number, size of the drainage area and estimated time to peak are presented.

The triangles represent reservoir routing locations. As shown, the computed hydrographs from Subwatersheds 3, 4, 5 and 6 were routed through a storage element prior to outletting downstream. The outlet location for each computed hydrograph is also marked on the figure.

The composite hydrograph in the centre of the figure represents the summation of all computed hydrographs. The dashed lines leading to the composite hydrograph box indicate that the addition of all of the subwatershed hydrographs does not physically occur. However, the concept of a composite hydrograph will be useful when comparing baseline condition flows with post-development flows from the site and when examining impacts of the development.

RESULTS

Flow estimates at each storm water outlet from the site are summarized in Table D14. Culvert sizes and capacities, top of road elevations, and 1:100 year water surface elevations at the culvert outlets are also presented for comparison.



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SCHEMATIC OF HYDROLOGIC MODEL

Figure D3

TABLE D14
OWMC PREFERRED SITE
EXISTING CONDITIONS AT CULVERT OUTLETS

Outlet Reference (See Figure 3.5)	Drainage Area (ha)	Outlet Size (Ø CSP-M)	Flow Estimates (m^3/s) Q100	Q50	Q10	Q5	Capacity of Culvert at Top of Road (m^3/s)	Top of Road Elev. (m)	1:100 Year Water Surface (m)	Downstream Swale Slope %
1	17.1	-	0.95	0.80	0.57	0.34	-	-	-	0.1
2	4.6	-	0.52	0.44	0.26	0.19	-	-	-	0.5
3a 3b 3c	14.2	0.30 0.40 0.30	0.35	0.33	0.20	0.14	0.43	183.8	183.7	0.2
4	31.1	0.60	0.46	0.41	0.30	0.25	0.57	183.7	183.4	0.1
5	61.5	0.60	0.56	0.52	0.43	0.36	0.56	183.6	183.6	0.1
6	3.8	0.30	0.08	0.07	0.05	0.04	0.08	184.7	184.7	0.1
7	2.0	0.76	0.30	0.25	0.15	0.11	0.40	184.8	184.7	0.5

The estimated 1:100 year storm water surface elevation will be at or near the top of the road at each culvert outlet. The approximate area of flooding upstream from each of these culverts (1:100 year storm) is shown on Figure 3.5. The composite site hydrograph shown on Figure D4 indicates an existing condition peak flow leaving the site of 2.06 m^3/s.

FLOW ESTIMATES - ALTERNATE METHODS

Whenever possible, secondary prediction techniques should be undertaken to confirm the validity of peak flow estimates. Secondary techniques which can generally be applied include:

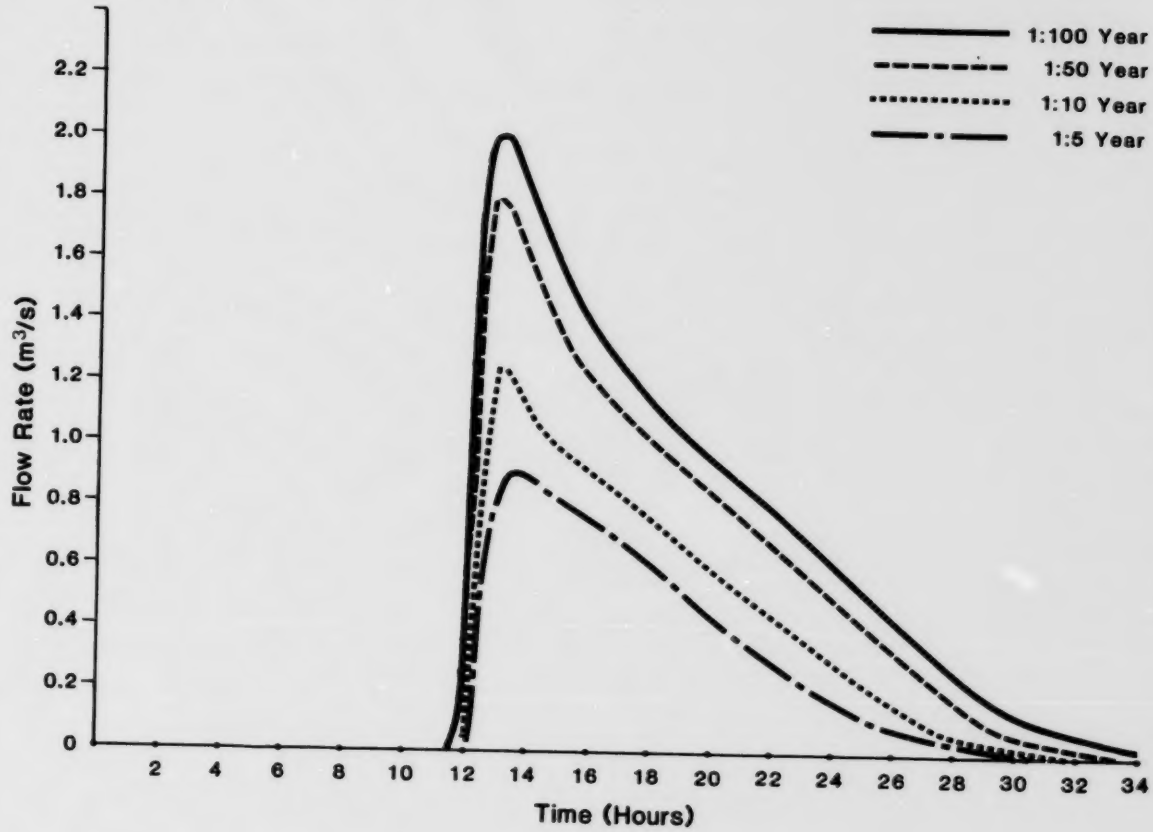
i) Regional Regression Equations, prepared by the Ministry of Natural Resources:

ii) the Index Flood Method, developed by Environment Canada;

iii) the MTC Modified Index Flood Method;

iv) the Rational Method.

Unfortunately, the relatively small size of the site drainage area renders the first three methods described above unacceptable for the purpose of checking peak flow estimates. Specifically, the Regression Equations identified in i) above were based on recorded data from basins ranging in size from 13 km^2 to 5900 km^2. Given the 1.3 km^2 site area, it is apparent that the regression equations do not have application. Similarly, the Index Flood Method was developed on the basis of recorded data from basins ranging from 63 km^2 to 293 km^2, while the MTC method was developed for computation of peak flows on basins in excess of 25 km^2.



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COMPOSITE HYDROGRAPHS FROM SITE

Figure D4

Consequently, the three regional based methods are not appropriate for peak flow estimates from the site, and would not serve as a suitable check on OTTHYMO generated flows.

The Rational Method is a popular method of estimating design flows and has been used since the late 1800's. It is considered to have application to small non-retentive rural watersheds and very small urban watersheds. The upper limit of area to which the method applies is highly debatable, but 25 km^2 is generally accepted for rural basins (MTC, 1984). Thus, it has application as a method of checking peak flow estimates from the site.

Rational Method peak flows are given by the following equation:

$$Q = .0028\ CiA$$

where Q = peak flow rate (m^3/s)
C = runoff coefficient
i = rainfall intensity (mm/hour)
A = drainage area hectares

Based on the heavy clay type soils representative of the site, a runoff coefficient of 0.45 was selected for each sub-watershed (MTC, 1984 and Chow, 1964).

Rainfall intensity values for each subwatershed were derived from time of concentration estimates (see Table D8) and from the Atmospheric Environment Service Vineland Station intensity-duration frequency data (see Table D2).

Subwatershed areas used in the equation were obtained from Table D9 and are identical to those used in the OTTHYMO model.

The Rational Method input data and peak flow estimates are summarized in Table D15. For comparison purposes, the Rational Method and OTTHYMO generated peak flow estimates are presented in Table D16. The OTTHYMO flows do not include the effects of storage upstream from outlets 3, 4, 5 and 6. It is necessary to omit this component for a consistent comparison of Rational Method and OTTHYMO generated flows, since the former is not capable of simulating the effects of storage on peak flows.

Observation of results presented in Table D16 indicates that the peak flow estimates using the two methods compare very favourably when storage effects are not considered.

TABLE D15
RATIONAL METHOD INPUT DATA AND PEAK FLOW ESTIMATES

Subwatershed No.	Runoff Coefficient	Time of Concentration (h)	Rainfall Intensity (mm/h)	Area (ha)	Estimated 1:100 Year Flow (m^3/s)
1	0.45	1.4	47	17.1	1.01
2	0.45	0.5	108	4.6	0.63
3	0.45	0.8	75	14.2	1.34
4	0.45	1.9	36	31.1	1.41
5	0.45	3.5	22	61.5	1.70
6	0.45	0.4	120	3.8	0.57
7	0.45	0.2	165	2.0	0.42

TABLE D16
COMPARISON OF OTTHYMO AND RATIONAL METHOD GENERATED PEAK FLOW ESTIMATES

Subwatershed No.	OTTHYMO Peak Flow (m^3/s)	Rational Method Peak Flow (m^3/s)
1	0.95	1.01
2	0.52	0.63
3	1.24	1.34
4	1.35	1.41
5	1.62	1.70
6	0.53	0.57
7	0.30	0.42

Notes:

i) OTTHYMO peak flow estimates do not include the effects of reservoir routing at the outlets from Subwatersheds 3, 4, 5 and 6.

ii) All flows in table result from 1:100 year storm.

APPENDIX E
SUCKER CREEK HYDROLOGIC/HYDRAULIC ASSESSMENT

APPENDIX E
SUCKER CREEK HYDROLOGIC/HYDRAULIC ASSESSMENT

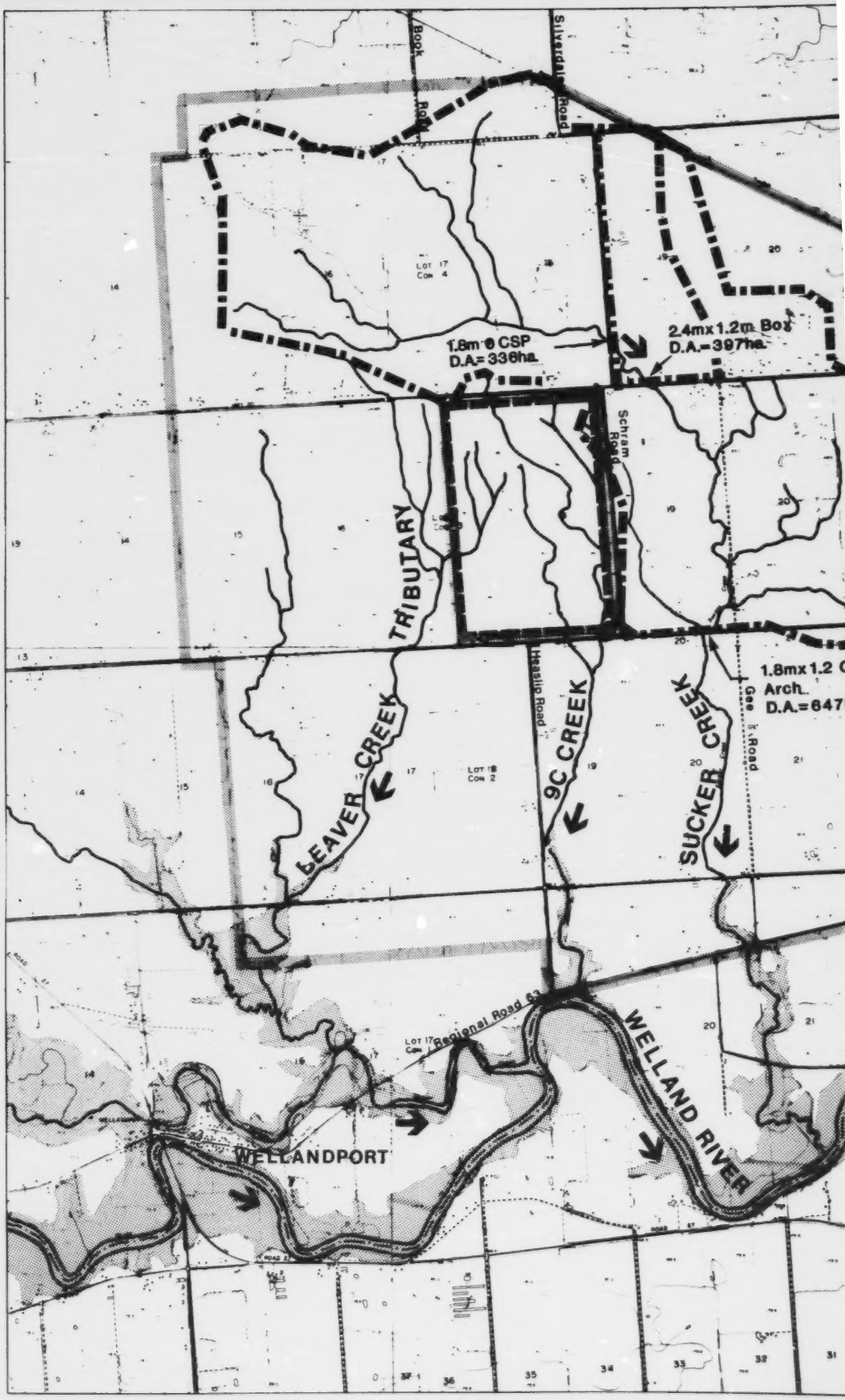
INTRODUCTION

Sucker Creek exists to the north and east of the site (as shown on Figure E1). It is the only watercourse of significance in the site vicinity which could potentially cause site flooding under extreme conditions. To assess the potential for Sucker Creek to flood the site, a simple hydrologic/hydraulic analysis was carried out. The methodology and the results are described in the following sections.

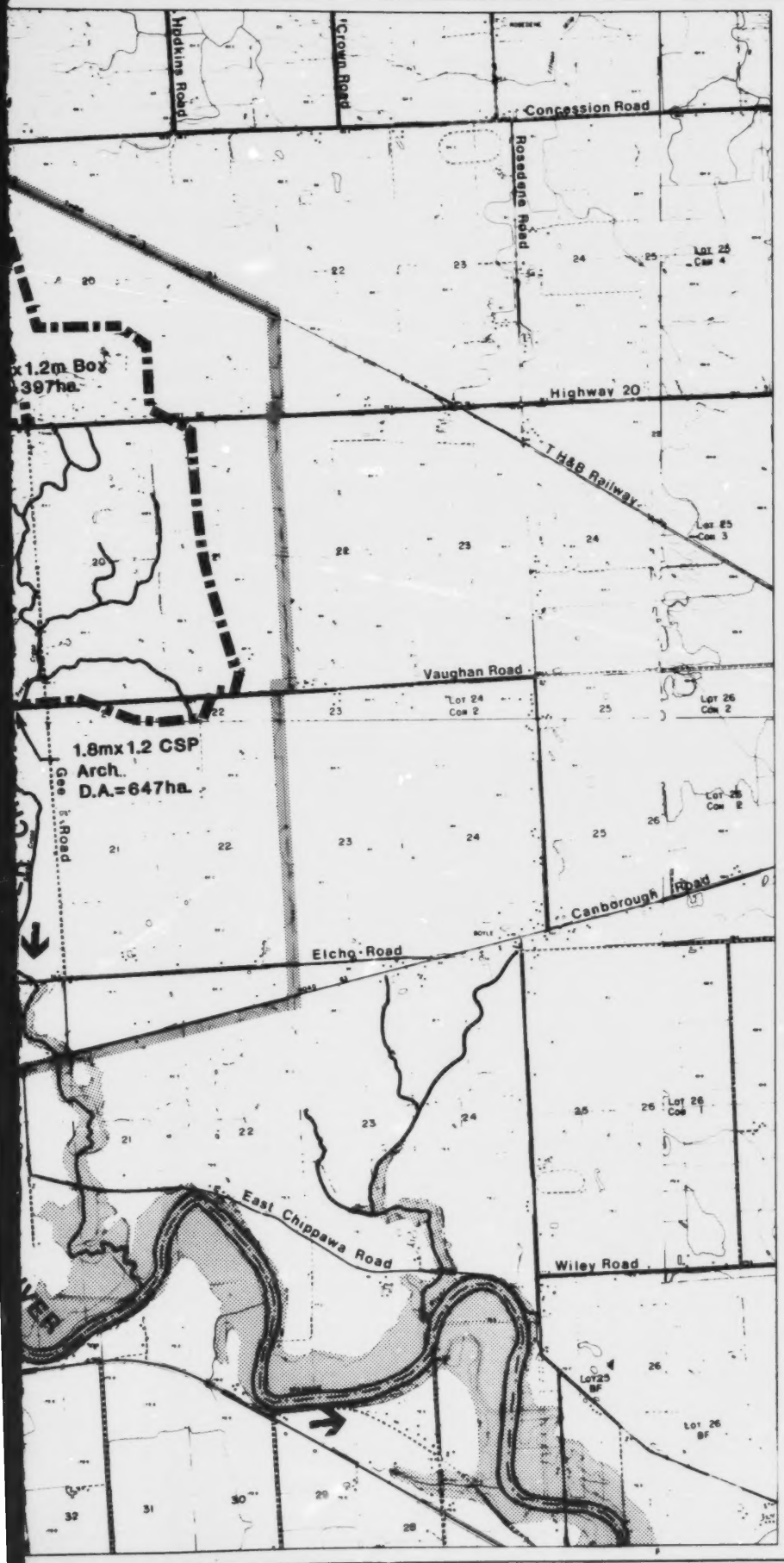
2. HYDROLOGIC ASSESSMENT

GENERAL

The headwaters of Sucker Creek originate to the north of the site between Highway 20 and the Toronto, Hamilton and Buffalo Railway Line. The creek drains in an easterly direction, just north of the site to a 1.8 m Ø CSP crossing beneath Silverdale Road (approximately 0.25 km north of the site). The watershed area contributing runoff to this point comprises 336 ha. This includes the extreme northeast corner of the site (2.0 ha). From the Silverdale Road crossing the creek drains in a southeast direction to a 2.4 m x 1.2 m box culvert under Highway 20 (approximately 0.25 km east of the site). The drainage area to this point is approximately 397 ha. The creek drains in a southerly direction from Highway 20 to a third crossing (1.8 m x 1.2 m CSP arch) beneath Vaughan Road. This crossing is located approximately 0.43 km east of the site and drains an upstream area of 647 ha. From Vaughan Road, the creek drains in a southerly direction and discharges directly to the Welland River.



Book Road
Silverdale Road
Lot 17 Con 4
1.8m ø CSP
D.A.=336ha.
2.4mx1.2m Box
D.A.=397ha.
Schram Road
TRIBUTARY
Heaslip Road
9C CREEK
SUCKER CREEK
Gee Road
1.8mx1.2 C
Arch.
D.A.=647h
LEAVER CREEK
Lot 18 Con 2
Regional Road 63
Lot 17 Con 1
WELLAND RIVER
WELLANDPORT



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Consultant:

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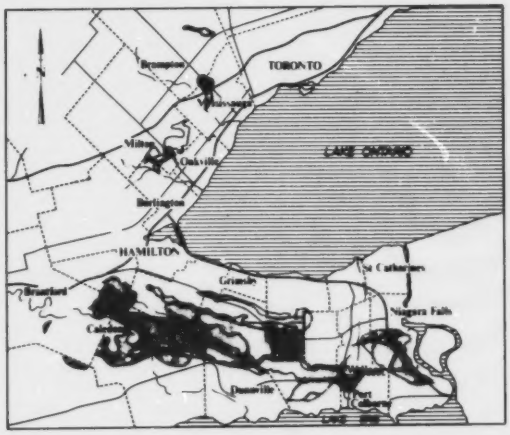
Legend:

- Sucker Creek Watershed Boundaries
- CSP – Corrugated Steel Pipe Culvert
- D.A. – Upstream Drainage Area
- Site Boundary
- Flow Direction
- Welland River Regulatory Floodline

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: OWMC PREFERRED SITE

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

SUCKER CREEK WATERSHED (TO VAUGHAN ROAD) AND WELLAND RIVER REGULATORY FLOODLINES

Figure E.1

The three crossings described above (Silverdale Road, Highway 20 and Vaughan Road) are of significance since their limited capacities could potentially cause back-up of Sucker Creek flood waters onto the site. To assess this potential, Regional Storm and 1:100 year storm peak flows were calculated at these locations using the OTTHYMO watershed model. The details of this model are described in Appendix D.

INPUT DATA - OTTHYMO MODEL

For simplicity, three separate models were set up to estimate peak flows at the three crossings of interest. At each crossing, flows were estimated by incorporating the entire upstream drainage area into a single subwatershed area. The subwatershed areas for each model are shown on Figure E1.

Input data for each model included Regional Storm and 1:100 year hyetographs (see Tables E1 and D4 respectively), drainage areas, times to peak, runoff curve numbers, number of linear reservoirs and initial abstraction. A discussion of the origin and significance of these parameters is given in Appendix D and is not repeated here. All input data for the Sucker Creek models is summarized in Table E2.

TABLE E1
REGIONAL STORM HYETOGRAPH

Time Hours:Minutes	Rainfall Intensity (mm/h)	Time Hours:Minutes	Rainfall Intensity (mm/h)	Time Hours:Minutes	Rainfall Intensity (mm/h)
0:00	0	4:00	13	8:00	13
0:10	6	4:10	17	8:10	13
0:20	6	4:20	17	8:20	13
0:30	6	4:30	17	8:30	13
0:40	6	4:40	17	8:40	13
0:50	6	4:50	17	8:50	13
1:00	6	5:00	17	9:00	13
1:10	4	5:10	13	9:10	53
1:20	4	5:20	13	9:20	53
1:30	4	5:30	13	9:30	53
1:40	4	5:40	13	9:40	53
1:50	4	5:50	13	9:50	53
2:00	4	6:00	13	10:00	53
2:10	6	6:10	23	10:10	38
2:20	6	6:20	23	10:20	38
2:30	6	6:30	23	10:30	38
2:40	6	6:40	23	10:40	38
2:50	6	6:50	23	10:50	38
3:00	6	7:00	23	11:00	38
3:10	13	7:10	13	11:10	13
3:20	13	7:20	13	11:20	13
3:30	13	7:30	13	11:30	13
3:40	13	7:40	13	11:40	13
3:50	13	7:50	13	11:50	13
				12:00	13

TABLE E2
SUCKER CREEK HYDROLOGIC MODELLING
OTTHYMO INPUT PARAMETERS

Model No.	Flow Estimate Location	Drainage Area (hectares)	Time to Peak (Hours)	Curve Number 1:100 Year	Regional	Linear Reservoirs (n)	Initial Abstraction (mm)
1	Silverdale Road	336	2.1	79	91	3	10
2	Highway 20	397	2.5	79	91	3	10
3	Vaughan Road	647	3.4	79	91	3	10

INPUT DATA - RATIONAL METHOD

The Rational method has been used to verify the Sucker Creek flow estimates using the OTTHYMO model. Rational method flow estimates are derived using the equation:

$Q = 0.0028\ CiA$ Where Q = Peak flow estimates (m^3/s)
C = Runoff coefficient
i = rainfall intensity (mm/h)
A = Drainage area (hectares)

A runoff coefficient of 0.45 has been selected as being representative of the heavy clay soils in the area. Rainfall intensities have been obtained from the Vineland Station gauge data on the basis of time of concentration estimates using the Uplands (grassed waterway) method. Drainage areas are identical to those used in the OTTHYMO model. Rational Method input data for Sucker Creek is given in Table E3.

TABLE E3
RATIONAL METHOD INPUT DATA AND FLOW ESTIMATES - SUCKER CREEK

Flow Estimate Location	Drainage Area (Hectares)	Time of Concentration (Hours)	Rainfall Intensity (mm/h)	Runoff Coefficient	1:100 Year Flow Estimate (m^3/s)
Silverdale Road	336	3.5	22	0.45	9.3
Highway 20	397	4.2	18	0.45	9.0
Vaughan Road	647	5.7	14	0.45	11.4

RESULTS

OTTHYMO generated Regional Storm and 1:100 year peak flow estimates at Silverdale Road, Highway 20 and Vaughan Road are presented in Table E4. This table also presents the 1:100 year Rational Method estimates for comparison purposes. Since the Regional Storm is a historical event without an associated return period, the Rational Method cannot be used to provide flow estimates for comparison with OTTHYMO generated Regional Storm flows. From the results presented, the 1:100 year Rational Method flows are in close agreement with the OTTHYMO generated flows. Therefore, peak flow estimates of 26.3 m^3/s (Regional) and 9.6 m^3/s (1:100 year), 28.5 m^3/s (Regional) and 9.8 m^3/s (1:100 year) and 39.1 m^3/s (Regional) and 12.1 m^3/s (1:100 year) were used to estimate flood levels upstream from the Silverdale Road, Highway 20 and Vaughan Road crossings respectively.

TABLE E4
SUCKER CREEK FLOW ESTIMATES

	OTTHYMO Model		Rational Method
	Regional Storm (m^3/s)	1:100 Year (m^3/s)	1:100 Year m^3/s
Silverdale Road	26.3	9.6	9.3
Highway 20	28.5	9.8	9.0
Vaughan Road	39.1	12.1	11.4

3. HYDRAULIC ANALYSIS

To determine whether or not site flooding could occur as a result of the limited capacity of the Silverdale Road, Highway 20 and/or Vaughan Road culverts, a hydraulic assessment of each culvert and roadway (overflow weir) was undertaken.

Culvert capacities were developed on the basis of inlet control nomographs (Bureau of Public Roads, 1965). Weir flow estimates were developed using the standard weir flow equation given by the following:

$Q = CLH^{1.5}$ Where Q = flow rate (m^3/s)
C = weir coefficient = 1.66 (metric)
L = weir length (m)
H = head on weir (m)

Road profiles and culvert data (geometry, inverts, obverts, etc.) were obtained from detailed field survey. A comparison of the field survey data with the 1:2000 scale, 0.5 m contour interval topographic mapping indicated very good agreement between the two.

Stage-discharge rating curves were developed for each crossing by combining the culvert and weir flow estimates at the appropriate stages. Tables E5, E6 and E7 provide summaries of the stage-discharge data and other information relevant to the estimation of upstream water levels at each crossing.

TABLE E5
SUCKER CREEK ANALYSIS
SILVERDALE ROAD STAGE-DISCHARGE-RELATIONSHIP

Water Surface Elevation (m)	Culvert Capacity (m^3/s)	Maximum Depth Over Road (m)	Flow Over Road (m^3/s)	Total Flow (m^3/s)
182.1	0.0	-	-	0.0
183.9	4.8	-	-	4.8
184.3	6.2	-	-	6.2
184.7 (top of road)	7.4	0.0	0.0	7.4
184.9	7.9	0.2	19.3	27.2

i) Culvert capacities computed by inlet control.

ii) Culvert = 1.8 m Ø CSP.

iii) Obvert elevation = 183.9 m, Invert elevation = 182.1 m.

iv) Minimum top of road = 184.7 m.

v) Regional Storm flow estimate = 26.3 m^3/s.

vi) 1:100 Year Storm flow estimate = 9.6 m^3/s.

TABLE E6
SUCKER CREEK ANALYSIS
HIGHWAY 20 STAGE-DISCHARGE RELATIONSHIP

Water Surface Elevation (m)	Culvert Capacity (m^3/s)	Maximum Depth Over Road (m)	Flow Over Road (m^3/s)	Total Flow (m^3/s)
181.8	0.0	-	-	0.0
183.0	4.5	-	-	4.5
183.5	6.7	-	-	6.7
184.1 (top of road)	8.7	0.0	0.0	8.7
184.2	9.2	0.1	3.0	12.2
184.3	9.4	0.2	14.2	23.6
184.5	9.6	0.3	33.1	42.7

i) Culvert capacities computed by inlet control.

ii) Culvert = 2.4 m x 1.2 m box.

iii) Obvert Elevation = 183.0 m, Invert Elevation = 181.8 m.

iv) Minimum top of road = 184.1 m.

v) Regional Storm flow estimate = 28.5 m^3/s.

vi) 1:100 Year Storm flow estimate = 9.8 m^3/s.

TABLE E7
SUCKER CREEK ANALYSIS
VAUGHAN ROAD STAGE-DISCHARGE RELATIONSHIP

Water Surface Elevation (m)	Culvert Capacity (m^3/s)	Maximum Depth Over Road (m)	Flow Over Road (m^3/s)	Total Flow (m^3/s)
178.7	0.0	-	-	0.0
179.9	2.6	-	-	2.6
180.0	2.8	-	-	2.8
180.5	4.0	0.0	0.0	4.0
181.0 (top of road)	4.8	0.0	0.0	4.8
181.2	5.0	0.2	6.2	11.2
181.4	5.4	0.4	24.8	30.2
181.6	5.5	0.6	56.4	61.9

i) Culvert capacities computed by inlet control.

ii) Culvert = 1.8 m x 1.2 m CSP Arch.

iii) Obvert Elevation = 179.9 m, Invert Elevation = 178.7 m.

iv) Minimum top of road = 181.0 m.

v) Regional Storm flow estimate = 39.1 m^3/s.

vi) 1:100 Year Storm flow estimate = 12.1 m^3/s.

Pertinent flow and water surface elevation data presented in Tables E5, E6 and E7 is summarized in Table E8 below.

TABLE E8
SUCKER CREEK ANALYSIS
SUMMARY OF FLOW AND WATER SURFACE ELEVATION ESTIMATES

	REGIONAL STORM		1:100 YEAR	
Location	Flow Estimate (m^3/s)	Water Surface Elevation (m)	Flow Estimate (m^3/s)	Water Surface Elevation (m)
Silverdale Road	26.3	184.9	9.6	184.7
Highway 20	28.5	184.5	9.8	184.2
Vaughan Road	39.1	181.5	12.1	181.3

The areas encompassed by the Regional Storm flood elevations immediately upstream from each road crossing are shaded on Figure 3.5. This shading indicates there is potential for Sucker Creek flooding to have a minor impact on the site upstream from Silverdale Road. The analysis also indicates that Sucker Creek flooding will not likely impact the site at the other two crossings (Highway 20 and Vaughan Road). The impact upstream from Silverdale Road is expected to be minor due to the following:

i) flooding would be limited to backflow through the two culverts beneath Highway 20;

ii) even though a very extreme event (Regional Storm) has been selected for analysis, the flood level is still approximately one metre below the Highway 20 top of road;

iii) backflow would likely be of short duration;

iv) the water level estimate is probably conservatively high since the vast storage volume upstream from Silverdale Road has not been accounted for in the computation;

v) site grading and perimeter berms will not allow backflow through the site.

In summary, the only watercourse of significance which could potentially flood the site is Sucker Creek, which exists to the north and east of the site. However, a hydrologic/hydraulic assessment of the most likely flooding locations (upstream from the Silverdale Road, Highway 20 and Vaughan Road crossings) indicates that even Regional Storm flood levels will have little or no impact on the site.

APPENDIX F

HISTORY OF NIAGARA RIVER POWER DEVELOPMENT NEAR THE WELLAND RIVER OUTLET

APPENDIX F
HISTORY OF NIAGARA RIVER DEVELOPMENT NEAR THE WELLAND RIVER OUTLET

The Niagara River is approximately 58 km (36 miles) in length and conveys an average flow in excess of 5700 m^3/sec (200,000 cfs) from Lake Erie to Lake Ontario. This world famous River is unique in that the elevation difference between the two lakes is about 100 m (326 ft.), a substantial portion of which is taken up by the Falls. The large flow and concentration of fall at Niagara Falls have created a scenic spectacle, and a hydro-electric power resource of great value. Both Canada and the United States have given attention and attached high priority over the years to preservation and use of these assets.

Water was first diverted from the Canadian side of the Niagara River for generation of electricity in 1893. An intake and power plant were built above the Horseshoe Falls to power an electric railway between the communities of Chippawa and Queenston. By the mid-1920s, a number of power plants had been constructed on both the Canadian and American sides of the Niagara River, upstream from the Horseshoe and American Falls. These intakes had little effect on Niagara River water levels upstream, where the Welland River emptied to the Niagara River.

The most significant development which had taken place by the mid 1920s was the construction of the Sir Adam Beck - Niagara Generating Station No. 1, which for many years was the largest hydro-electric plant in the world. To utilize the maximum fall of the Niagara River, water had to be diverted from an intake 3 km above the Horseshoe Falls to the plant at the base of the Niagara Gorge. This intake consisted of a 20 km long open canal waterway from Chippawa to a forebay on the escarpment, more than 90 m above the Niagara River.

The construction of the intake is significant to this study, since it altered the natural outlet of the Welland River to the Niagara River. Prior to the construction of this intake, the Welland River flowed in an easterly direction, outletting to the Niagara River through the Town of Chippawa. Ontario Hydro utilized the last 6 km of the Welland River as the initial portion of their intake, by dredging this section and reversing the direction of flow. This flow reversal was accomplished by providing a new outlet approximately 6 km west of Chippawa (immediately east of the point where the existing Queen Elizabeth Way crosses the Welland River). This new outlet channel, which is comprised of trapezoidal and rectangular cross sections, conveys water north from the Welland River, then north-east through the City of Niagara Falls, to the power plant forebay.

From the completion of the open canal/waterway system in the early 1920s, until 1942, the reverse flow at the Welland River intake system was controlled by the natural fluctuations of the Niagara River water levels and the controlled level at the plant forebay. There was no structure on the Niagara River to control water levels, or the amount of water diverted from the Niagara River for purposes of power production.

In 1942, construction was begun on a submerged rock weir part way across the Niagara River to satisfy the following criteria;

i) increase the power output from plants on both sides of the Niagara River;

ii) reduce ice-jamming problems in the river and at the brink of the falls;

iii) improve the appearance of the American Falls.

This weir was designed to satisfy the criteria described above, by raising the water level immediately upstream of the weir by approximately 0.3 m (1 ft.) at low stage. The construction and effects of this weir on water levels are documented in the report by the Construction subcommittee. (Niagara River Remedial Works - Submerged Weir, Final Progress Report of Construction Subcommittee, 1 September 1948).

To utilize the potential benefits of increased power production from the Niagara River, Ontario Hydro began construction of another larger power plant (Beck No. 2) in 1951. To increase the flow to the plants, another intake system from the Niagara River was required. Two tunnels were constructed beneath the City of Niagara Falls, with the intakes located just downstream from the original Beck No. 1 (Welland River) intake on the Niagara River. The construction of this new intake system had no direct impact on the Welland River intake system, since it consisted of two underground tunnels, separate and distinct from the Welland River and the previously constructed Beck No. 1 intake. However, the combined capacity of the two intake systems was now sufficient to significantly reduce the flow over the Falls, and to reduce water levels in the Niagara River (and hence in the Welland River). To compensate for this drawdown effect, the International Control Structure was built in 1955.

This gated control structure replaced the submerged rock weir (described previously) and afforded more control of flows over the falls, levels in the Chippawa-Grass Island pool and ice-jamming problems. The Power Authorities were directed by the International Niagara Board of Control (INBC) to operate this structure such that the relationship between Niagara River flows and levels remain essentially the same as that which prevailed prior to 1953.

Construction began on the large U.S. Niagara Moses plant in the late 1950s. By 1961, this plant was fully operational, with a potential capacity of 2970 m^3/s (105,000 cfs). The intake for this plant draws water from the Chippawa-Grass Island pool, near Conners Island, upstream from the Beck No. 1 intake. Both of the U.S. plants which were operational prior to 1961 (Schoellkopf and Adams) were retired with start-up of the Moses plant.

To compensate for the increased diversion from the Chippawa-Grass Island pool, and to improve the control of flow over the falls, five additional gates were added to the control structure by 1963.

The Toronto Power Plant was retired in the early 1970s, while the low efficiency Ontario Power Plant is still operational, as is the American-owned Canadian-Niagara plant.

2.0 HISTORY OF NIAGARA RIVER REGULATION

2.1 FLOW DIVERSION RESTRICTIONS

Prior to the construction of the submerged rock weir (1942) Niagara River water levels were unregulated, and influenced the water levels in the Welland River. The Niagara River levels depended on flow rate, which in turn were influenced mainly by Lake Erie levels. Therefore, high Lake Erie levels (caused by high runoff and/or wind set-up) resulted in high Niagara River flows and hence high levels in the Lower Welland River. Similarly, low Lake Erie levels and the resultant low Niagara River flows caused low levels in the Lower Welland River.

As development on the Niagara River for power production purposes increased, restrictions were put on the maximum amount of water that could be withdrawn from the river. The Boundary Waters treaty of 11 January 1909, permitted the withdrawal of up to 56,000 cfs for power production purposes. However, with the advent of World War II, and the resultant increase in power requirements, the Canadian and U.S. governments agreed in 1940 to increase the maximum withdrawal rate for power purposes to 82,500 cfs. To forestall the adverse effects of this increased withdrawal rate on the appearance of the Falls, consideration was given to alternative means of controlling Niagara River water levels.

2.2 SUBMERGED ROCK WEIR

Regulation of Niagara River levels began in 1942 when it was determined that the appearance of the American Falls could be improved and power production increased by constructing a submerged weir part way across the Niagara River. The weir was constructed between 1942 and 1947. During this period and right up until 1948, Ontario Hydro undertook a field program including soundings, survey of channel sections and flow measurements to determine the effect of the weir on water levels and ice build-up. Field results indicated that under normal flow conditions, the weir increased the water surface elevation immediately upstream by approximately 1 ft. This difference was reduced to about 0.7 ft. at the Material Dock. It was also noted that the difference in pre- and post-weir levels decreased as the Niagara River flow rate increased.

2.3 REVISED FLOW DIVERSION RESTRICTIONS

In February 1950, the permissible withdrawal rate from the Niagara River was revised by putting a minimum value on the flow rate which had to go over the Falls, the remainder of which could go

for power production purposes. This 1950 Treaty was a contrast to earlier Treaties, which allowed a maximum rate to be withdrawn for power production purposes, the remainder of which would go over the Falls. Basically this new Treaty required a Falls flow of not less than 2830 m^3/s (100,000 cfs) during daylight hours of the tourist season, and 1415 m^3/s (50,000 cfs) at any other time.

2.4 INTERNATIONAL NIAGARA BOARD OF CONTROL REGULATION, 1955 DIRECTIVE

With more water available under the terms of the 1950 Treaty, Canadian and U.S. Power Authorities devised new means of utilizing this excess flow with minimum impact on the Niagara River and the appearance of the Falls. The Beck No. 2 generating station was built in the mid-1950s, along with a gated concrete control structure to mitigate the effects of the increased diversion.

After the development of Beck No. 2 and the International Control Structure, the Power Authorities were issued a directive (in 1955) from the International Niagara Board of Control, regarding maintenance of water levels on the Niagara River near the Welland River intake. This directive essentially required that the Authorities operate the control structure such that the daily water level in the Chippawa-Grass Island Pool did not vary more than 0.15 m (0.5 ft.), nor monthly mean stage more than 0.09 m (0.3 ft.) from the pre-1953 hydraulic regime. This directive was issued to minimize the impact of the Power Authorities' operation on the overall system. A mathematical equation relating the natural water level to flow rate was used in maintaining this natural condition.

2.5 INTERNATIONAL NIAGARA BOARD OF CONTROL REGULATIONS, 1973 DIRECTIVE

The maintenance of natural condition water levels and the regulations regarding minimum flow over the Falls were held from 1955 until 1973, when the International Niagara Board of Control issued another directive, requiring revised operation of the control structure. This revision directed that the control structure be operated to maintain the long-term mean level of the Chippawa-Grass Island Pool at elevation 171.0 m (IGLD) as recorded at the Material Dock gauge. To provide the latitude to facilitate control of flow over the Falls and to the Power diversions, the Board established the following tolerances:

a) the continuous, arithmetically accumulated monthly deviations from elevation 171.0 m (IGLD) shall not exceed 3.0 foot-months;

b) the change in the monthly mean level from one month to the next shall not exceed 0.15 m;

c) the maximum range of fluctuation in the Pool level during a calendar day shall not exceed 0.46 m;

d) the pool level shall not be raised above 171.45 m (IGLD) nor lowered below 170.54 m (IGLD) feet except for abnormal flow* or ice conditions;

* Abnormal flow conditions are considered to exist when any four consecutive hourly mean Niagara River flows, as measured at the Fort Erie gauge, are greater than 7646 m^3/s or less than 4248 m^3/s. Under ice conditions, this flow is the discharge indicated by the Fort Erie gauge corrected for ice effect.

e) during abnormal flow or ice conditions, the following tolerances shall apply:

i) pool level shall not exceed 171.6 m (IGLD) nor be less than 170.38 m (IGLD);

ii) normal operating procedures shall be resumed within 12 hours following the last abnormal flow period.

Items (a) to (e) above summarize the control procedure the Power Authorities have been been directed to follow by the International Niagara Board of Control. One of the major reasons for the 1973 revisions to the operation of the control structure was to alleviate complaints from landowners along the Niagara River regarding the widely fluctuating water levels under natural conditions.

3.0 EXISTING SYSTEM CONTROL

In order to ensure that the tolerances set out in the INBC 1973 directive are followed, Ontario Hydro must continuously monitor flow rates and water levels at several locations on the Niagara River/Welland River/Power Canal system. For the purposes of this study, the most important gauge locations and their functions are described below.

i) flow gauge located at Fort Erie which indicates the total flow available in the Niagara River;

ii) level gauge at the Material Dock, which is used to ensure the Chippawa-Grass Island pool does not exceed or drop below the limits dictated by the 1973 directive;

iii) level gauge at Montrose, which is useful for determination of maximum and minimum water surface elevations which occur where the Welland River discharges into the Power Canal;

iv) level gauge at the Beck Crossover point which indicates the tailwater used to partially control flow through the Power Tunnels and the Power Canal;

v) Ashland Avenue flow gauge below the falls which is used to monitor the flow over the falls (which does not include the water diverted for power purposes).

A brief summary of how the data described above is used for system control is given below:

- day-to-day operation is controlled by Hydro staff at the control structure on the Niagara River;

- the flow gauge at Fort Erie is monitored continuously so that Power Authorities know the Niagara River flow rate, and therefore know how much water is available for diversion for power production purposes;

- minimum flows over the falls of 2832 m^3/s during the day in the tourist season, and 1416 m^3/s the rest of the time are maintained by observing the continuous flow record provided by the Ashland Avenue gauge. When the flow over the falls nears the minimum allowable values as set by the INBC, then the Power Authorities must reduce the amount of water which

is being diverted accordingly. The control structure rating curves are also useful for predicting what flow is passing the structure and hence going over the falls;

- along with maintaining a minimum flow over the Falls, the criteria regarding water level fluctuations at the Material Dock gauge must also be satisfied (171.0 m $\pm$ .46m) (IGLD).

  This is accomplished by continuously monitoring the Material Dock levels. When it appears as though this level will rise above or drop below the tolerable limits, an adjustment must be made at the crossover point and/or at the Niagara River control structure. The control of the Material Dock water level is complicated by the fact that the accumulated monthly deviation from level 171.0 m (IGLD) may not exceed 3 foot months, the change in monthly mean may not vary by more than 0.15 m. from one month to the next, and the daily fluctuation may not exceed 0.46 m.

The control of water levels and operation of the Niagara River system within the INBC requirements is certainly a complex task. While the Power Authorities are responsible for the operation within the strict criteria set out by the INBC, these criteria were not selected to maximize the Power Authorities' benefit. In fact, the regulation regards power production as secondary to preservation of the Falls and reduction in water level fluctuations upstream on the Niagara River.

In summary, Ontario and New York Power Authorities control the system and operate within the INBC criteria, by continuously monitoring data from numerous flow and level gauges in the area. The flow diverted through the Beck No. 1 intake by Ontario Hydro at any time is dependent on the water levels at the upstream and downstream ends of the intake system (Material Dock and Beck Crossover respectively). Since the water level at both of these

locations can be controlled, the amount of flow being diverted for power production can also be controlled. If Ontario Hydro operated in their own best interest (i.e. maximum power production), they would minimize the difference between the Beck Crossover and Material Dock level, therefore, maximizing the flow through the Chippawa Canal and also minimizing the Niagara River water level. Higher Niagara River water levels would result in higher levels in the Welland River, potentially increasing the flooding problems in the lower reach. The restrictions imposed by the INBC prevent this from occurring.

APPENDIX G

WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA

APPENDIX G
WATER QUALITY GUIDELINES
OBJECTIVES AND CRITERIA

Tables G1 to G104 describe all available water quality guidelines, objectives and criteria for the protection of:

- ambient water
- drinking water
- aquatic species
- agriculture (livestock watering and irrigation)
- recreational and aesthetic uses of water.

The information contained in these tables was collected from criteria developed by national and international sources. A discussion of these criteria is included in Appendix I.

TABLE G1
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
pH

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		6.5-8.5			
Ontario Water Management Goal, Policies and Objectives	6.5-8.5			4.5-9.0	
Great Lakes Water Quality Agreement	6.5-8.5				
Environment Canada		6.5-8.3	7.0-9.2		6.5-8.3
Health & Welfare Canada					6.5-8.3
World Health Organization		6.5-8.3			
U.S. EPA			6.5-9.0	4.5-9.0	5.0-9.0

TABLE G2
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dissolved Oxygen (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives	4-8				
Great Lakes Water Quality Agreement			6.0		
Environment Canada			>4		
Health & Welfare Canada					
World Health Organization					
U.S. EPA			5.0		

TABLE G3
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Total Dissolved Solids (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		500			
Ontario Water Management Goal, Policies and Objectives				1000-3000	
Great Lakes Water Quality Agreement			200		
Environment Canada		1000			
Health & Welfare Canada		500			500
World Health Organization		1000			
U.S. EPA					

TABLE G4
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Turbidity (NTU)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		1			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada		5			
World Health Organization		5*			
U.S. EPA					

*preferably <1 for disinfection purposes

TABLE G5
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Alkalinity (mg/L as CaCO3)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		30-500			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA			20		

TABLE G6
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Total Organic Carbon (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		5.0			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABL3 G7
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Sodium (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		20			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		200			
U.S. EPA					

TABLE G8
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Calcium (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives				1000	
Great Lakes Water Quality Agreement					
Environment Canada		200			
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G9
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Magnesium (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives				700	
Great Lakes Water Quality Agreement					
Environment Canada		150			
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G10
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Fluoride (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		2.4 1.2			
Ontario Water Management Goal, Policies and Objectives				1-15	
Great Lakes Water Quality Agreement		1.2			
Environment Canada		1.2		1.0 - 15	
Health & Welfare Canada		1.2			
World Health Organization		1.5			
U.S. EPA		0.6-1.7			

TABLE G11
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Chloride (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		250			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada		250			
Health & Welfare Canada		250			
World Health Organization		250			
U.S. EPA					

TABLE G12
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Ammonia (mg/L as NH3)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.02		
Great Lakes Water Quality Agreement		0.5	0.02		
Environment Canada		0.05		5.0	
Health & Welfare Canada					
World Health Organization					
U.S. EPA			0.02		

TABLE G13
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Total Kjeldahl Nitrogen (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.15-0.2			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G14
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Total Phosphorus, Phosphate (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives	0.01-0.1				
Great Lakes Water Quality Agreement					
Environment Canada	0.01-0.1				
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G15
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Nitrate (mg/L as NO3)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		45			
Ontario Water Management Goal, Policies and Objectives				400 - 450	
Great Lakes Water Quality Agreement					
Environment Canada		45		450	
Health & Welfare Canada		45			
World Health Organization		45			
U.S. EPA		45			

TABLE G16
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Biochemical Oxygen Demand (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada	<4 clean >10 polluted				
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G17
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Total Coliform (/100 mL)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		5			
Ontario Water Management Goal, Policies and Objectives					1000
Great Lakes Water Quality Agreement					
Environment Canada	5000	10			
Health & Welfare Canada		10			
World Health Organization		0-10			
U.S. EPA					

TABLE G18
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Fecal Coliform (/100 mL)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0			
Ontario Water Management Goal, Policies and Objectives					100
Great Lakes Water Quality Agreement					
Environment Canada	1000	0			100 - 400
Health & Welfare Canada		0			200
World Health Organization		0			
U.S. EPA				100	200

TABLE G19
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Fecal Streptococci (/100 mL)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada	50				
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G20
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Background (Standard Plate Count) (/mL)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		500			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G21
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Arsenic (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		50			
Ontario Water Management Goal, Policies and Objectives			100	100 - 2000	
Great Lakes Water Quality Agreement		50			
Environment Canada			10 - 50	100 - 2000	
Health & Welfare Canada		50			
World Health Organization		50			
U.S. EPA		50	440		

TABLE G22
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Cadmium (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		5			
Ontario Water Management Goal, Policies and Objectives			0.2	10-50	
Great Lakes Water Quality Agreement			0.2		
Environment Canada	10	10	0.2	50	10
Health & Welfare Canada		5			
World Health Organization		5			
U.S. EPA		10*		10-50	

*proposed Recommended Maximum Contaminant Level = 5 ug/L

TABLE G23
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Chromium (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.05			
Ontario Water Management Goal, Policies and Objectives			0.1	1.0	
Great Lakes Water Quality Agreement		0.05			
Environment Canada		0.1	0.04	0.1 - 1.0	0.1
Health & Welfare Canada		0.05			
World Health Organization		0.05			
U.S. EPA	170	0.12*	100-400 (CrIII) 11 (CrVI)		

*proposed Recommended Maximum Contaminant Level

TABLE G24
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Cyanide (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		200			
Ontario Water Management Goal, Policies and Objectives			5		
Great Lakes Water Quality Agreement					
Environment Canada		200			
Health & Welfare Canada		200	5		
World Health Organization		100			
U.S. EPA		200	5		

TABLE G25
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Lead (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.05			
Ontario Water Management Goal, Policies and Objectives	0.005 - 0.025			0.1-10	
Great Lakes Water Quality Agreement			0.01-0.02		
Environment Canada		0.05	0.01	0.1-10	
Health & Welfare Canada		0.05			
World Health Organization		0.05			
U.S. EPA		0.05	0.02*	0.1-10	

*proposed Recommended Maximum Contaminant Level

TABLE G26
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Mercury (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		1.0			
Ontario Water Management Goal, Policies and Objectives	0.2			10	
Great Lakes Water Quality Agreement			0.2		
Environment Canada			0.2		
Health & Welfare Canada		1.0			
World Health Organization		1.0			
U.S. EPA	0.144	0.003*	0.012		

* proposed Recommended Maximum Contaminant Level

TABLE G27
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Sulfide (ug/L as H2S)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			2		
Great Lakes Water Quality Agreement			2.0		
Environment Canada			2		
Health & Welfare Canada					
World Health Organization		not detectable by consumer			
U.S. EPA					

TABLE G28
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Aluminum (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.1			
Ontario Water Management Goal, Policies and Objectives				5.0 - 20.0	
Great Lakes Water Quality Agreement					
Environment Canada			0.1		
Health & Welfare Canada					
World Health Organization		0.2			
U.S. EPA					

TABLE G29
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Copper (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		1.0			
Ontario Water Management Goal, Policies and Objectives			0.005	0.2-5	
Great Lakes Water Quality Agreement			0.005		
Environment Canada		0.5	0.005	0.2-0.5	
Health & Welfare Canada		1.0			
World Health Organization		1.0			
U.S. EPA	1	1.3*	0.01-0.02	0.2-5	

* proposed Recommended Maximum Contaminant Level

TABLE G30
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Iron (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.3			
Ontario Water Management Goal, Policies and Objectives			0.3	5-20	
Great Lakes Water Quality Agreement			0.3		
Environment Canada		0.3	0.3	5-20	
Health & Welfare Canada		0.3			
World Health Organization		0.3			
U.S. EPA			1	5-20	0.3

TABLE G31
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Manganese (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.05			
Ontario Water Management Goal, Policies and Objectives				0.2 - 10	
Great Lakes Water Quality Agreement					
Environment Canada		0.05	0.02	0.2 - 10	
Health & Welfare Canada		0.05			
World Health Organization		0.1			
U.S. EPA					

TABLE G32
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Zinc (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		5.0			
Ontario Water Management Goal, Policies and Objectives			0.03		
Great Lakes Water Quality Agreement			0.03		
Environment Canada					
Health & Welfare Canada		5.0			
World Health Organization		5.0			
U.S. EPA		5.0*	0.047		

* for control of undesirable taste and odour

TABLE G33
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Phenol (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		2			
Ontario Water Management Goal, Policies and Objectives			1		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada		2			
World Health Organization					
U.S. EPA		3500	2560		

TABLE G34
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Monochlorophenols (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			7		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		0.1			
U.S. EPA			4380		

TABLE G35
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dichlorophenols (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.2		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		0.1			
U.S. EPA		3800	365		

TABLE G36
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Trichlorophenols (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			18		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		10-toxic 0.1 - aesthetic			
U.S. EPA		1.2-2600			

TABLE G37
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Tetrachlorophenols (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			1		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		0.1			
U.S. EPA					

TABLE G38
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Pentachlorophenol (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.5		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		10-toxic 0.1 - aesthetic			
U.S. EPA		1010	3.2		

TABLE G39
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dinitrophenols (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	70				

TABLE G40
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dinitro-o-cresol (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	13.4				

TABLE G41
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
2,4-Dimethylphenol (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		0.4			

TABLE G42
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Di-2-ethylhexylphthalate (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.006		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	15.0		0.003		

TABLE G43
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dibutylphthalate (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.004		
Great Lakes Water Quality Agreement			0.004		
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	34		0.003		

TABLE G44
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dimethylphthalate (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.002		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	313		0.003		

TABLE G45
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Diethylphthalate (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.002		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	350		0.003		

TABLE G46
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Chlorobenzene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			15		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		3			
U.S. EPA		488			20

TABLE G47
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dichlorobenzenes (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goals, Policies and Objectives			2.5-4		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		0.1-0.3			
U.S. EPA		0.4	3.0		

TABLE G48
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Trichlorobenzenes (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.5-0.9		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G49
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Tetrachlorobenzenes (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.1-0.15		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		38			

TABLE G50
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Pentachlorobenzene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.03		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		74			

TABLE G51
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Hexachlorobenzene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.0065		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		0.01			
U.S. EPA					

TABLE G52
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Bis(chloromethyl)ether (ng/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.0038*				

* 1/1,000,000 cancer risk

TABLE G53
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Bis(2-chloroethyl)ether (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.03*				

* 1/1,000,000 cancer risk

TABLE G54
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Bis(2-chloroisopropyl)ether (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	34.7				

TABLE G55
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Hexachloroethane (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	1.9*		540		

* 1/1,000,000 cancer risk

TABLE G56
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Hexachlorobutadiene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		206-toxic 1.0 - aesthetic			

TABLE G57
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Hexachlorocyclopentadiene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	5.2*				

* 1/1,000,000 cancer risk

TABLE G58
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Nitrobenzene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		19800 - toxic 30 - aesthetic			

TABLE G59
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
2,4-Dinitrotoluene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.11*		230		

* 1/1,000,000 cancer risk

TABLE G60
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Benzidine (ng/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.12*				

* 1/1,000,000 cancer risk

TABLE G61
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
3,3-Dichlorobenzidine (ng/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	10.3*				

* 1/1,000,000 cancer risk

TABLE G62
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
1,2-Diphenylhydrazine (ng/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	42*				

* 1/1,000,000 cancer risk

TABLE G63
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Nitrosamines (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.0014* 4.9**				

* 1/1,000,000 cancer risk for N-nitrosodimethylamine
** 1/1,000,000 cancer risk for N-nitrosodiphenylamine

TABLE G64
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Isophorone (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	5.2	117			

TABLE G65
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Biphenyl (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	13.8				

TABLE G66
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Naphthalene (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA			620		

TABLE G67
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Chloronaphthalene (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA			1.6		

TABLE G68
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Carbon Tetrachloride (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		3			
U.S. EPA	0.4*	5			

* 1/1,000,000 cancer risk

TABLE G69
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
1,2-Dichloroethane (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		10			
U.S. EPA		5	20000		

TABLE G70
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Trichloroethanes (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	18.4*	0.2*	9400**		

* 1,1,1-Trichloroethane
** 1,1,2-Trichloroethane

TABLE G71
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
1,1,2,2-Tetrachloroethane (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.17*		2400		

* 1/1,000,000 cancer risk

TABLE G72
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Vinyl Chloride (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		1			

TABLE G73
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
1,1-Dichloroethylene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		0.3			
U.S. EPA		7			

TABLE G74
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
1,2-Dichloroethylene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		70			

TABLE G75
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Trichloroethylene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		30			
U.S. EPA		5			

TABLE G76
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Tetrachloroethylene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		10			
U.S. EPA					

TABLE
TABLE G77
Dichloropropanes (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		6	5700		

TABLE G78
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Dichloropropenes (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	87		244		

TABLE G79
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Trihalomethanes (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.35*			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada		0.35*			
World Health Organization		0.03**			
U.S. EPA					

* Total chloroform, bromodichloromethane, chlorodibromomethane, and bromoform
** Chloroform only

TABLE G80
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Benzene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		10			
U.S. EPA		5			

TABLE G81
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Toluene (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	14.3	2	17.5		

TABLE G82
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Ethylbenzene (mg/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	1.4	0.68	32		

TABLE G83
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Xylenes (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		440			

TABLE G84
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Acrolein (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	320		21		

TABLE G85
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Acrylonitrile (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.58*				

* 1/1,000,000 cancer risk

TABLE G86
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Polynuclear Aromatic Hydrocarbons (PAHs) (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization		0.01*			
U.S. EPA	20** 42***				

* Benzo(a)pyrene
** Acenaphthene
*** Fluoranthene

TABLE G87
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Polychlorinated Biphenyls (PCBs) (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		3			
Ontario Water Management Goal, Policies and Objectives			0.001		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA	0.000079*		0.014		

* 1/1,000,000 cancer risk

TABLE G88
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Aldrin - Dieldrin (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.7			
Ontario Water Management Goal, Policies and Objectives			0.001	1.0	
Great Lakes Water Quality Agreement	0.001				
Environment Canada	17				
Health & Welfare Canada		0.7			
World Health Organization		0.03			
U.S. EPA			3-Aldrin 1.9 - Dieldrin		

TABLE G89
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Chlordane (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		7			
Ontario Water Management Goal, Policies and Objectives	0.06			3	
Great Lakes Water Quality Agreement			0.06		
Environment Canada	3				
Health & Welfare Canada		7			
World Health Organization		0.3			
U.S. EPA	0.0043		2.4		

TABLE G90
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Parathion (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		35			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada		35			
World Health Organization					
U.S. EPA					

TABLE G91
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Methylparthion (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		7			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada		7			
World Health Organization					
U.S. EPA					

TABLE G92
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Diazinon (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		14			
Ontario Water Management Goal, Policies and Objectives			0.08		
Great Lakes Water Quality Agreement			0.08		
Environment Canada	100				
Health & Welfare Canada		14			
World Health Organization					
U.S. EPA					

TABLE G93
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Lindane (gamma-BHC) (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		4			
Ontario Water Management Goal, Policies and Objectives	0.01			5	
Great Lakes Water Quality Agreement			0.01		
Environment Canada	56				
Health & Welfare Canada		4			
World Health Organization		3			
U.S. EPA			0.08		

TABLE G94
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Heptachlor & Heptachlor Epoxide (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		3			
Ontario Water Management Goal, Policies and Objectives			0.001	0.1	
Great Lakes Water Quality Agreement	0.001				
Environment Canada	18				
Health & Welfare Canada		3			
World Health Organization		0.1			
U.S. EPA			0.0038		

TABLE G95
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Endrin (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.2			
Ontario Water Management Goal, Policies and Objectives			0.002	0.5	
Great Lakes Water Quality Agreement	0.002				
Environment Canada		1			
Health & Welfare Canada		0.2			
World Health Organization					
U.S. EPA		1	0.0023		

TABLE G96
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Endosulfan (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.003		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA		74	0.056		

TABLE G97
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Mirex (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives			0.001		
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada					
World Health Organization					
U.S. EPA			0.001		

TABLE G98
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Methoxychlor (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		0.1			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada	35				
Health & Welfare Canada		0.1			
World Health Organization		30			
U.S. EPA		100			

TABLE G99
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
DDT-T (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		30			
Ontario Water Management Goal, Policies and Objectives			0.003	50	
Great Lakes Water Quality Agreement	0.003				
Environment Canada	42				
Health & Welfare Canada		30			
World Health Organization		1			
U.S. EPA			1.1		

TABLE G100
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Silvex (2,4,5-TP) (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		10			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada	100				
Health & Welfare Canada		10			
World Health Organization					
U.S. EPA		10			

TABLE G101
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
2,4,5-T (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada	100				
Health & Welfare Canada					
World Health Organization					
U.S. EPA					

TABLE G102
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
2,4-D (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		100			
Ontario Water Management Goal, Policies and Objectives	4				
Great Lakes Water Quality Agreement					
Environment Canada	100				
Health & Welfare Canada		100			
World Health Organization		100-toxic 50 - aesthetic			
U.S. EPA		100			

TABLE G103
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Alachlor (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives		1			
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada		5			
World Health Organization					
U.S. EPA					

TABLE G104
WATER QUALITY GUIDELINES, OBJECTIVES AND CRITERIA
Toxaphene (ug/L)

CRITERIA JURISDICTION	RECEPTORS				
	Ambient	Drinking Water	Aquatic Habitat	Agricultural	Recreational & Aesthetic
Ontario Drinking Water Objectives					
Ontario Water Management Goal, Policies and Objectives					
Great Lakes Water Quality Agreement					
Environment Canada					
Health & Welfare Canada		0.005 - aesthetic			
World Health Organization					
U.S. EPA	0.00071*		0.0013		

* 1/1,000,000 cancer risk

APPENDIX H
PRIORITY POLLUTANT SELECTION

APPENDIX H
PRIORITY POLLUTANT SELECTION

Priority pollutant and pesticide parameters for analysis in this study were selected from a compilation of three lists of organic chemicals analyzed by reputable bodies for highly respected water quality assessments.

These were:

- EPA 129 priority pollutant list (EPA129);
- MOE St. Clair River Study (MOE ST CL);
- MOE Niagara River Study (MOE NIAG).

After the lists were compiled the abilities of the contract laboratories, Barringer Magenta Limited (BML) and Mann Testing Laboratories (MANN), to analyze the various priority organics was assessed. The results of this preliminary selection are shown in Table H1.

As well, the concern over each chemical was documented in Table H2. The final selection of priority pollutants and pesticides was based on the capability of the laboratories to conduct the analysis and the level of concern raised over the chemical. For example, if the laboratories were not capable of analyzing an organic contaminant and the contaminant was of low toxicity or used minimally in Ontario - the contaminant was not analyzed in this study. The final listing of priority organics selected is shown in Appendix A.

TABLE H1
PRIORITY ORGANICS SELECTION

PARAMETER	APPEARED ON ANALYSIS LISTS			LAB CAP	
	MOE ST CL	EPA 129	MOE NIAG	BML	MANN
chloromethane	YES	YES	YES	YES	YES
chloroform	YES	YES	YES	YES	YES
bromoform	YES	YES	YES	YES	YES
dichlorobromomethane	YES	YES	YES	YES	YES
dibromochloromethane	YES	YES	YES	YES	YES
carbon tetrachloride	YES	YES	YES	YES	YES
1,1-dichloroethane	YES	YES	YES	YES	YES
1,2-dichloroethane	YES	YES	YES	YES	YES
1,1,1-trichloroethane	YES	YES	YES	YES	YES
1,1,2-trichloroethane	YES	YES	YES	YES	YES
1,1,2,2-tetrachloroethane	YES	YES	YES	YES	YES
1,1-dichloroethylene	YES	YES	YES	YES	YES
1,2-t-dichloroethylene	YES	YES	YES	YES	YES
trichloroethylene	YES	YES	YES	YES	YES
tetrachloroethylene	YES	YES	YES	YES	YES
1,2-dichloropropane	YES	YES	NO	YES	YES
1,2-dichlorobenzene	YES	YES	YES	YES	YES
1,3-dichlorobenzene	YES	YES	YES	YES	YES
1,4-dichlorobenzene	YES	YES	YES	YES	YES
hexachloroethane	YES	YES	NO	YES	YES
pentachloropropene	YES	NO	NO	NO	NO
hexachloropropene	YES	NO	NO	NO	NO
tetrachlorobutane	YES	NO	NO	NO	NO
pentachlorobutadiene	YES	NO	NO	NO	NO
hexachlorobutadiene	YES	YES	YES	YES	YES
benzene	YES	YES	YES	YES	YES
toluene	YES	YES	YES	YES	YES
phenol	YES	YES	YES	YES	YES
ethylbenzene	YES	YES	YES	YES	YES
o-xylene	YES	NO	YES	YES	YES
m-xylene	YES	NO	YES	YES	YES
p-xylene	YES	NO	YES	YES	YES
biphenyl	YES	NO	YES	NO	YES
fluoroanthene	YES	YES	YES	YES	YES
naphthalene	YES	YES	NO	YES	YES
methylphenanthrene	YES	NO	YES	YES	YES
chlorobenzene	YES	YES	YES	YES	YES
1,2,3-trichlorobenzene	YES	NO	YES	NO	YES
1,2,4-trichlorobenzene	YES	YES	YES	YES	YES
1,3,5-trichlorobenzene	YES	NO	NO	NO	YES
1,2,3,4-tetrachlorobenzene	YES	NO	YES	NO	YES
1,2,3,5-tetrachlorobenzene	YES	NO	NO	NO	YES
1,2,4,5-tetrachlorobenzene	YES	NO	YES	NO	YES
pentachlorobenzene	YES	NO	YES	NO	YES
hexachlorobenzene	YES	YES	YES	YES	YES
2,3,6-trichlorotoluene	YES	NO	YES	YES	YES

TABLE H1
PRIORITY ORGANICS SELECTION

PARAMETER	APPEARED ON ANALYSIS LISTS			LAB CAP	
	MOE ST CL	EPA 129	MOE NIAG	BML	MANN
2,4,5-trichlorotoluene	YES	NO	YES	YES	YES
2,6,A-trichlorotoluene	YES	NO	NO	NO	YES
trifluorochlorotoluene	YES	NO	NO	NO	NO
2,3,4-trichlorophenol	YES	NO	YES	NO	YES
2,4,5-trichlorophenol	YES	NO	YES	NO	YES
2,4,6-trichlorophenol	YES	YES	YES	YES	YES
2,3,4,5-tetrachlorophenol	YES	NO	NO	NO	YES
2,3,5,6-tetrachlorophenol	YES	NO	YES	NO	YES
pentachlorophenol	YES	YES	YES	YES	YES
PCB	YES	YES	YES	YES	YES
PCDF	YES	NO	NO	NO	YES
PCDD	YES	YES	YES	NO	YES
diphenylether	YES	NO	YES	NO	YES
di-n-butylphthalate	YES	YES	YES	YES	YES
N-dichloromethyleneCl(5)anilin	YES	NO	NO	NO	NO
aldrin	YES	YES	YES	YES	YES
alpha-BHC	YES	YES	YES	YES	YES
beta-BHC	YES	YES	YES	YES	YES
gamma-BHC(lindane)	YES	YES	YES	YES	YES
alpha-chlordane	YES	YES	YES	YES	YES
gamma-chlordane	YES	YES	YES	YES	YES
dieldrin	YES	YES	YES	YES	YES
methoxychlor	YES	NO	YES	YES	YES
endrin	YES	YES	YES	YES	YES
endosulfan sulfate	YES	YES	NO	YES	YES
a-endosulfan-alpha	YES	YES	YES	YES	YES
b-endosulfan-beta	YES	YES	YES	YES	YES
methylparathion	YES	NO	YES	NO	YES
parathion	YES	NO	YES	NO	YES
heptachlor	YES	YES	YES	YES	YES
heptachlor epoxide	YES	YES	YES	YES	YES
mirex	YES	NO	YES	YES	YES
oxychlordane	YES	NO	YES	NO	YES
o,p-DDT	YES	NO	YES	NO	YES
p,p-DDD	YES	YES	YES	YES	YES
p,p-DDE	YES	YES	YES	YES	YES
p,p-DDT	YES	YES	YES	YES	YES
ametrine	YES	NO	NO	NO	YES
atrazine	YES	NO	NO	NO	YES
diazinon	YES	NO	YES	NO	YES
bladex	YES	NO	NO	NO	NO
prometone	YES	NO	NO	NO	NO
propazine	YES	NO	NO	NO	NO
prometryne	YES	NO	NO	NO	NO
sencor	YES	NO	NO	NO	NO
simazine	YES	NO	NO	NO	NO

TABLE H1
PRIORITY ORGANICS SELECTION

PARAMETER	APPEARED ON ANALYSIS LISTS MOE ST CL	EPA 129	MOE NIAG	LAB CAP BML	MANN
dicamba	YES	NO	NO	NO	NO
picloram	YES	NO	NO	NO	NO
silvex	YES	NO	YES	YES	YES
2,4-D	YES	NO	YES	YES	YES
2,4-D butyric acid	YES	NO	NO	NO	NO
2,4-D propionic acid	YES	NO	NO	NO	NO
2,4,5-T	YES	NO	YES	YES	YES
acenaphthene	NO	YES	NO	YES	YES
acrolein	NO	YES	NO	YES	YES
acrylonitrile	NO	YES	NO	YES	YES
benzidine	NO	YES	NO	YES	YES
chloroethane	NO	YES	NO	YES	YES
bis(chloromethyl)ether	NO	YES	NO	YES	YES
bis(2-chloroethyl)ether	NO	YES	NO	YES	YES
2-chloroethyl vinyl ether	NO	YES	NO	NO	NO
2-chloronaphthalene	NO	YES	YES	YES	YES
p-chloro-meta-cresol	NO	YES	NO	NO	YES
2-chlorophenol	NO	YES	NO	YES	YES
3,3'-dichlorobenzidine	NO	YES	NO	YES	YES
2,4-dichlorophenol	NO	YES	YES	YES	YES
1,3-dichloropropene	NO	YES	NO	YES	YES
2,4-dimethylphenol	NO	YES	NO	YES	YES
2,4-dinitrotoluene	NO	YES	NO	YES	YES
2,6-dinitrotoluene	NO	YES	NO	YES	YES
1,2-diphenylhydrazine	NO	YES	NO	YES	YES
4-chlorophenyl phenyl ether	NO	YES	NO	YES	YES
4-bromophenyl phenyl ether	NO	YES	NO	YES	YES
bis(2-chloroisopropyl)ether	NO	YES	NO	YES	YES
bis(2-chloroethoxy)methane	NO	YES	NO	YES	YES
chloromethane	NO	YES	NO	YES	YES
bromoethane	NO	YES	NO	YES	YES
trichlorfluoromethane	NO	YES	NO	YES	YES
dichlorodifluoromethane	NO	YES	NO	YES	YES
hexachlorocyclopentadiene	NO	YES	NO	YES	YES
isophorone	NO	YES	NO	YES	YES
2-nitrophenol	NO	YES	NO	YES	YES
4-nitrophenol	NO	YES	NO	YES	YES
2,4-dinitrophenol	NO	YES	NO	YES	YES
4,6-dinitro-o-cresol	NO	YES	NO	YES	YES
N-nitrosodimethylamine	NO	YES	NO	YES	YES
N-nitrosodiphenylamine	NO	YES	NO	YES	YES
bis(2-ethylhexyl)phthalate	NO	YES	NO	YES	YES
butyl benzyl phthalate	NO	YES	NO	YES	YES
di-n-octylphthalate	NO	YES	YES	YES	YES
diethyl phthalate	NO	YES	YES	YES	YES
dimethyl phthalate	NO	YES	NO	YES	YES

TABLE H1
PRIORITY ORGANICS SELECTION

PARAMETER	APPEARED ON ANALYSIS LISTS			LAB CAP	
	MOE ST CL	EPA 129	MOE NIAG	BML	MANN
vinyl chloride	NO	YES	NO	YES	YES
endrin aldehyde	NO	YES	NO	YES	YES
delta-BHC	NO	YES	NO	YES	YES
toxaphene	NO	YES	YES	YES	YES
PAHs	NO	YES	YES	YES	YES
N-nitroso-n-propylamine	NO	YES	NO	YES	YES
nitrobenzene	NO	YES	NO	YES	YES
benzaldehyde	NO	NO	YES	NO	NO
2-chlorotoluene	NO	NO	YES	NO	YES
4-chlorotoluene	NO	NO	YES	NO	YES
hexanal	NO	NO	YES	NO	NO
hexane	NO	NO	YES	NO	NO
styrene	NO	NO	YES	NO	NO
alachlor	NO	NO	NO	YES	YES

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
chloromethane	Identified in the Niagara River. Evidence of carcinogenicity in rats. Extensively used in the manufacture of solvents, insecticides, spray products and fire extinguishers. Affects O2 carrying capacity of blood. Analyzed for on all lists.
chloroform	Identified in the Niagara River. Of major concern in drinking water as a result of chlorination processes. Identified as a known carcinogen. Analyzed for on all lists.
bromoform	See chloroform.
dichlorobromomethane	See chloroform.
dibromochloromethane	See chloroform.
carbon tetrachloride	Identified in the Niagara and St. Clair Rivers. Carcinogenic and produced in large quantities. Analyzed on all lists.
1,1-dichloroethane	Analyzed for in all lists but no toxicity information available. Not identified in either MOE study.
1,2-dichloroethane	Identified in the Niagara River. Used as an intermediate in the production of vinyl chloride and 1,1,1-trichloroethane. Mutagenic and carcinogenic. Analyzed in all lists.
1,1,1-trichloroethane	Identified in the Niagara River. Used as a solvent. Exhibits toxic effects to liver, kidneys and nervous system. Analyzed in all lists.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
1,1,2-trichloroethane	Listed by EPA as a carcinogen. Analyzed on all lists.
1,1,2,2-tetrachloroethane	Listed by EPA as a carcinogen. Analyzed on all lists.
1,1-dichloroethylene	Also commonly called vinylidene chloride. Insufficient evidence of human carcinogenicity. Shows carcinogenic effects in animals. Toxic effects to the liver in human exposures. Analyzed in all lists.
1,2-t-dichloroethylene	MOE name does not include trans designation. Minimal human exposure data available. Animal studies show carcinogenic effects to liver and kidney. Analyzed on all lists.
trichloroethylene	Identified in the Niagara River. Mutanogenic and carcinogenic. Analyzed in all lists.
tetrachloroethylene	Identified in the St. Clair River. Also commonly called perchloroethylene. Mutanogenic and carcinogenic impacting mainly the liver. Analyzed on all lists.
1,2-dichloropropane	No specific toxicity information available. Analyzed in all lists except the Niagara River study. Environmental Defense Fund listing shows no toxic effects for dichloropropane.
1,2-dichlorobenzene	Identified in the Niagara River. Exhibits toxic effects in the human liver and kidney. Analyzed in all lists.
1,3-dichlorobenzene	See 1,2-dichlorobenzene.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
1,4-dichlorobenzene	See 1,2-dichlorobenzene. Also supected as being the most carcinogenic of the three dichlorobenzenes.
hexachloroethane	Identified by the EPA as a carcinogen .Analyzed in all lists except Niagara River.
pentachloropropene	No specific toxicity information available. Analyzed only in the MOE St. Clair River study because of suspected manufacture or use in the area. Pentachloropropene was not found in detectable quantities in any water samples taken in that study. Therefore it is not necessary to analyze for pentachloropropene in the OWMC study.
hexachloropropene	See pentachloropropene.
tetrachlorobutane	MOE designation not explicit enough. See pentachloropropene.
pentachlorobutadiene	See pentachloropropene.
hexachlorobutadiene	Identified by EPA as a carcinogen. Analyzed in all lists.
benzene	Identified in the Niagara and St. Clair Rivers. Known carcinogen which may cause anemia and leukemia. Analyzed in all lists.
toluene	Identified in the Niagara River. No carcinogenic, mutanogenic or teratogenic effects. Major observable human health effect is central nervous system depression. Analyzed on all lists.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
phenol	Exhibits toxic effects in humans. Analyzed in all lists.
ethylbenzene	Identified in the Niagara River. Ethylbenzene impacts the liver, kidney and nervous systems. It appears not to be mutagenic, carcinogenic, or teratogenic. Analyzed on all lists.
o-xylene	Identified in the Niagara River. Not considered a priority pollutant by the EPA. Analyzed in both the Niagara and St. Clair River studies. As the labs are capable of analyzing for xylenes, Dillon recommends their inclusion in the OWMC list.
m-xylene	See o-xylene.
p-xylene	See o-xylene.
biphenyl	Not considered a priority pollutant by the EPA. MOE analyzed for biphenyl in both the St. Clair and Niagara River studies. No detectable quantities were identified. No toxicity information is available. Therefore Dillon recommends excluding biphenyl from the OWMC list.
fluoroanthene	See PAHs.
naphthalene	See PAHs.
methylphenanthrene	EPA may list under different name. See PAHs.
chlorobenzene	Identified in the Niagara River. May cause cancer. Effects include central nervous system depression, headache, dizziness, muscle spasms and liver and kidney damage. Analyzed in all lists.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
1,2,3-trichlorobenzene	Identified in the Niagara River. Not considered a priority pollutant by the EPA. However, the MOE considers chlorinated benzenes to be of concern in Ontario. No toxicity information available. Dillon recommends inclusion of the chlorinated benzenes on the OWMC list.
1,2,4-trichlorobenzene	See 1,2,3-trichlorobenzene. Included on the EPA priority pollutant list.
1,3,5-trichlorobenzene	See 1,2,3-trichlorobenzene. Not identified in the Niagara River.
1,2,3,4-tetrachlorobenzene	See 1,2,3-trichlorobenzene. Not identified in the Niagara River.
1,2,3,5-tetrachlorobenzene	Analyzed only in the St. Clair River study as the MOE considered it of concern due to local production or use of the chemical. 1,2,3,5-tetrachlorobenzene was identified in the St. Clair River. Dillon considers it questionable whether analysis for this chemical is necessary in the OWMC as local use is not anticipated.
1,2,4,5-tetrachlorobenzene	Not considered a priority pollutant by the EPA. Analyzed for in both the Niagara and St. Clair River studies. Identified in the St. Clair River. Dillon recommends inclusion of this chemical on the OWMC list because it is shown to give toxic effects in humans and it is considered of concern by MOE.
pentachlorobenzene	See 1,2,4,5-tetrachlorobenzene.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
hexachlorobenzene	Identified in the Niagara and St. Clair Rivers. Mutagenic, carcinogenic and posibly teratogenic. Analyzed on all lists.
2,3,6-trichlorotoluene	Identified in the Niagara River. Not considered a priority pollutant by the EPA. Chlorinated toluenes are considered to be of concern by the MOE in Ontario. No toxicity information available. Dillon recommends inclusion of the chlorinated toluenes on the OWMC list to meet MOE concerns.
2,4,5-trichlorotoluene	See 2,3,6-trichlorotoluene.
2,6,A-trichlorotoluene	This chemical was only analyzed for in the St. Clair River study because of concerns over its local production or use. It was not identified in the river. We feel that 2,6,A-trichlorotoluene does not warrent inclusion in the OWMC list because no local use or production is anticipated.
trifluorochlorotoluene	See 2,6,A-trichlorotoluene.
2,3,4-trichlorophenol	Identified in the Niagara River. Not considered a priority pollutant by the EPA but the MOE considers chlorinated phenols to be of concern in Ontario. Therefore, Dillon recommends inclusion on the OWMC list.
2,4,5-trichlorophenol	See 2,3,4-trichlorophenol.
2,4,6-trichlorophenol	Identified in the Niagara River. May have dioxin as an impurity. Suspected carcinogen. Analyzed on all lists.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
2,3,4,5-tetrachlorophenol	Analyzed only in the St. Clair River study because of concern over local production or use. No 2,3,4,5-tetrachlorophenol was identified in the St. Clair River. Therefore, Dillon recommends exclusion from the OWMC list because no local use or production of this chemical is anticipated.
2,3,5,6-tetrachlorophenol	See 2,3,4-trichlorophenol. Not identified in the Niagara River.
pentachlorophenol	Causes elevated blood pressure and increased respiration rate in humans. Although PCP use has been partially banned it is still extensively used as a wood preservative in Ontario. Analyzed on all lists.
PCB	EPA lists seven aroclors, 1016,1221,1232,1242,1248,1254, 1260. Identified in the Niagara River. Although the toxic effects of PCBs are questionable Dillon recommends that they be included on the OWMC list because of their extensive use and the broad public awareness to PCBs. As well, there is a great possibility that PCBs could be incinerated at the OWMC facility, therefore background PCB levels in the surface waters should be known.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
PCDF	PCDFs are a combustion byproduct of chlorinated organics. They are considered more toxic than PCBs and less toxic than PCDDs. Analysis of PCDFs has not been required on any of the lists. As PCBs, chlorinated organics and PCDDs are being analyzed, it is unnecessary, and costly, to analyze for PCDFs as well.
PCDD	PCDDs are considered extremely toxic, although their exact human carcinogenicity has not been proven. It is anticipated that no background levels of PCDDs will be identified in this study. However, it is recommended that at least a cursory analysis of the surface water for PCDD content be undertaken because of the proposed use of the site. Chlorinated organics will be incinerated at the OWMC facility and PCDDs could be produced. Therefore background PCDD levels must be identified for the impact assessment.
diphenylether	Identified as a chemical of concern in the St. Clair and Niagara River studies. Therefore, Dillon recommends inclusion in the OWMC list.
di-n-butylphthalate	Teratogenic but not carcinogenic or mutagenic. Analyzed in all lists.
N-dichloromethyleneCl(5)anilin	Reason for inclusion in MOE list is not obvious. No toxicity or production information is available. Therefore, Dillon recommends exclusion from the OWMC list.
aldrin	Persistent and carcinogenic. Analyzed on all lists.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
alpha-BHC	Identified in the Niagara River. Insecticide. Carcinogenic to the liver. Included on all lists.
beta-BHC	Carcinogenic insecticide. Included on all lists.
gamma-BHC(lindane)	See alpha-BHC.
alpha-chlordane	EPA listing is for chlordane and metabolites. Chlordane is described as a persistent, carcinogenic insecticide. Included on all lists. Identified in the Niagara River.
gamma-chlordane	EPA listing is for chlordane and metabolites. See alpha-chlordane.
dieldrin	Identified in the Niagara River. Persistent, carcinogenic insecticide. Identified on all lists
methoxychlor	Methoxychlor is an insecticide which has been extensively detected in food and water. However, it does not bioconcentrate,has a low order of toxicity and is rapidly excreted from the body. The MOE considers methoxychlor of concern in Ontario. Therefore Dillon recommends inclusion in the OWMC list.
endrin	Identified in the Niagara River. Endrin is persistent, bioaccumulative and carcinogenic. Identified on all lists.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
endosulfan sulfate	MOE listing is for "thiodan". Endosulphan and its metabolites exhibit toxic effects in humans. Therefore, Dillon recommends inclusion in the OWMC list.
a-endosulfan-alpha	MOE listing is for thiodan. See endosulfan sulfate.
b-endosulfan-beta	MOE listing is for thiodan II. See endosulfan sulfate.
methylparathion	Not considered a priority pollutant by the EPA. No toxicity information available. Considered of concern by the MOE because of use in Ontario. Therefore Dillon recommends inclusion in the OWMC list.
parathion	See methylparathion.
heptachlor	Persistent, bioaccumulative, carcinogenic insecticide. Included on all lists.
heptachlor epoxide	See heptachlor. Identified in the Niagara River.
mirex	Not considered a priority pollutant by the EPA. The MOE feels that mirex is of concern because of its use in Ontario. Therefore, Dillon recommends inclusion in the OWMC list.
oxychlordane	Not considered a priority pollutant by the EPA. MOE considers it of concern because of use in Ontario. Therefore, Dillon recommends inclusion in the OWMC list.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
o,p-DDT	Identified in the Niagara River. Highly stable and persistent. DDT has been banned from use and is carcinogenic. EPA does not include the o,p- isomer on its priority pollutant list. Dillon recommends inclusion, however, because of the extreme toxicity of the DDT family and because of MOEs concern for this isomer.
p,p-DDD	See o,p-DDT. Included on all lists. Not identified in the Niagara River.
p,p-DDE	See o,p-DDT. Identified on all lists.
p,p-DDT	See o,p-DDT. Identified on all lists.
ametrine	Herbicide. No specific toxicity information available. Ametrine was only analyzed for in the St. Clair River study because of specific use concerns. None was identified. Use of ametrine has not been identified in the Welland area. Therefore Dillon does not recommend inclusion of ametrine on the OWMC list.

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PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
atrazine	Atrazine is a herbicide which has a 'low order of chronic toxicity and is not carcinogenic'. Therefore, it is not commonly analyzed for in surface water studies. Atrazine is however, commonly found in water and is included in the herbicide packages from the contract labs. Therefore, although atrazine is not considered a 'problem herbicide' Dillon does recommend its inclusion in the OWMC list.
diazinon	Diazinon is an organophosphate pesticide that is used extensively on crops and animals. It impacts the nervous system but is not carcinogenic. Because of its relatively low toxicity the EPA does not include diazinon on its list of priority pollutants. The MOE feels that it is of concern because of its wide spread use. Therefore Dillon recommends inclusion in the OWMC list.
bladex	See atrazine.
prometone	See atrazine.
propazine	See atrazine.
prometryne	See atrazine.
sencor	See ametrine.
simazine	See atrazine.
dicamba	See ametrine.
picloram	See atrazine.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
silvex	Silvex is also called 2,4,5-TP. It is not carcinogenic but may contain TCDD. This causes silvex to be of concern to the MOE. Therefore Dillon recommends inclusion of silvex in the OWMC list.
2,4-D	2,4-D is a plant growth regulator. Health effects include fatigue, headache, liver damage, and loss of appetite. Not carcinogenic. Not included in the EPA priority pollutant list because of its relatively low toxicity. Of concern to MOE because of its wide spread use. Recommend inclusion.
2,4-D butyric acid	Likely to be present as 2,4-D and does not need to be included separately.
2,4-D propionic acid	Likely present as 2,4-D and does not need to be included separately.
2,4,5-T	See silvex.
acenaphthene	EPA priority pollutant. MOE does not consider it necessary to analyze for this chemical. However, the contract labs include the analysis as part of their `priority pollutant package'. Therefore, Dillon recommends inclusion for completeness.
acrolein	See acenaphthene.
acrylonitrile	See acenaphthene.
benzidine	See acenaphthene
chloroethane	See acenaphthene.
bis(chloromethyl)ether	See acenaphthene.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
bis(2-chloroethyl)ether	See acenaphthene.
2-chloroethyl vinyl ether	See acenaphthene.
2-chloronaphthalene	See acenaphthene.
p-chloro-meta-cresol	See acenaphthene.
2-chlorophenol	See acenaphthene.
3,3'-dichlorobenzidine	See acenaphthene.
2,4-dichlorophenol	See acenaphthene.
1,3-dichloropropene	See acenaphthene.
2,4-dimethylphenol	See acenaphthene.
2,4-dinitrotoluene	See acenaphthene.
2,6-dinitrotoluene	See acenaphthene.
1,2-diphenylhydrazine	See acenaphthene.
4-chlorophenyl phenyl ether	See acenaphthene.
4-bromophenyl phenyl ether	See acenaphthene.
bis(2-chloroisopropyl)ether	See acenaphthene.
bis(2-chloroethoxy)methane	See acenaphthene.
chloromethane	See acenaphthene.
bromoethane	See acenaphthene.
trichlorfluoromethane	See acenaphthene.
dichlorodifluoromethane	See acenaphthene.
hexachlorocyclopentadiene	See acenaphthene.
isophorone	See acenaphthene.
2-nitrophenol	See acenaphthene.
4-nitrophenol	See acenaphthene.
2,4-dinitrophenol	See acenaphthene.

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PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
4,6-dinitro-o-cresol	See acenaphthene.
N-nitrosodimethylamine	See acenaphthene.
N-nitrosodiphenylamine	See acenaphthene.
bis(2-ethylhexyl)phthalate	See acenaphthene.
butyl benzyl phthalate	See acenaphthene.
di-n-octylphthalate	See acenaphthene.
diethyl phthalate	See acenaphthene.
dimethyl phthalate	See acenaphthene.
vinyl chloride	See acenaphthene.
endrin aldehyde	See acenaphthene.
delta-BHC	See acenaphthene. Also identified in the Niagara River.
toxaphene	See acenaphthene.
PAHs	Thirteen listed by EPA. These are included in the labs' priority pollutant packages. Again because of potential impacts from incineration at the site, Dillon recommends that background levels of PAHs be determined, for impact assessment purposes.
N-nitroso-n-propylamine	See acenaphthene.
nitrobenzene	See acenaphthene.
benzaldehyde	Identified in the Niagara River. See styrene.
2-chlorotoluene	Identified in the Niagara River. See styrene.
4-chlorotoluene	Identified in the Niagara River. See styrene.

Table H2
PRIORITY ORGANIC SELECTION

COMPOUND	RATIONALE
hexanal	Identified in the Niagara River. See styrene.
hexane	Identified in the Niagara River. See styrene.
styrene	Identified in the Niagara River. Styrene's most severe toxic concern is through airborne exposure in the workplace. It was analyzed in the Niagara River because of specific concerns of leachate from the Hyde Park landfill. There are no related concerns in this context, therefore styrene need not be included in the OWMC list.
alachlor	Alachlor is extensively used herbicide in Ontario and other areas of North America. It has been identified in both treated and raw drinking water samples in Brantford and other Ontario cities. Alachlor is also suspected as being a human carcinogen. For these reasons alachlor was selected for analysis in the OWMC baseline water quality study.

APPENDIX I
WATER QUALITY CRITERIA SUMMARIES

APPENDIX I
WATER QUALITY CRITERIA SUMMARIES

In this appendix water quality criteria have been summarized to provide a basis for understanding the impact of the data produced by this study. The summaries have been developed from a variety of sources which are referenced in the summaries. In general, Ontario and Canadian drinking water standards and ambient water quality objectives were the first references consulted. The World Health Organization also provided information on water quality in the context of human consumption. Other specialized data reviews on specific groups of chemicals were consulted such as the documents on chlorobenzenes produced by the MOE, the chlorophenol publication from Environment Canada and the National Research Council documents on scientific criteria for environmental quality. For information not available from Canadian sources, the USEPA water quality criteria were consulted. These criteria were developed under a detailed set of requirements laid out in the U.S. Clean Water Act and deserve some additional comment.

The criteria developed by the USEPA meet the Clean Water Act requirement of providing "the latest scientific knowledge on the identifiable effects of pollutants on public health and welfare, aquatic life and recreation". The criteria are published for information and "may form the basis of enforceable standards". The criteria are typically very conservative in nature; this is a characteristic of the USEPA work that is well recognized (Environmental Science and Technology, May 1987, p.415). The criteria, as developed and published, document a variety of exposure times and conditions. For the purposes of this review criteria reflecting chronic exposure and cancer risk at the one in 1 000 000 probability level have been used.

The criteria assume a standard diet and drinking water consumption and the effects are summarized assuming multiple

sources of a contaminant. Finally, it is noted that different criteria may be found from other parts of the USEPA or other U.S. federal agencies. It is important that the precise logic of arriving at each criteria be understood to apply the criterion.

One significant problem in using these criteria is that they often suggest warning levels for contaminants that are well below the ability of modern analytical technology to detect or quantify the analyte. Typically these criteria are used as starting points and the ability of the analyst in practice to deliver reliable data is integrated into the final control level that is established. Clearly, many of these criteria reflect a status of thinking that is in advance of serious efforts to establish control limits.

GENERAL CHEMISTRY

Temperature

The water quality criterion for temperature in Ontario (MOE, 1984a) addresses the maximum temperature permitted in a discharge and the ambient temperature change caused by the discharge of heated water. General guidelines have been laid down to protect aquatic life. As well, a case by case assessment must be made to allow for special circumstances which may include specified temperature allowances and a zone where the temperature criteria may be applied (the mixing zone).

The maximum allowable discharge temperature permitted is 30°C measured at the edge of a mixing zone. The maximum temperature rise at the edge of a mixing zone is 10°C. The sensitivity of aquatic organisms may be found to be highly seasonal and local disruption in migration and reproductive cycles may have to be taken into account to modify these general guidelines.

Temperature is generally not a concern for drinking water in the context of the OWMC facility. Bacterial growth rates, which are increased by warmer water may impact potential downstream users of Welland River water as a raw water source for humans or livestock. Palatability is also affected by warmer temperatures.

pH

It is generally agreed (Environment Canada, 1979; MOE, 1983, MOE, 1984a; WHO, 1986) that water pH should be maintained within a range of 6.5 to 8.5. By maintaining surface water within this pH range aquatic organisms that can be impacted or even destroyed by large changes in pH will be protected. As well, surface waters with pH outside of this range may require specialized water treatment if used as a drinking water supply. This is because high pH water may cause mineral encrustation and low pH water may corrode water pipes.

Dissolved Oxygen

The presence or absence of dissolved oxygen in drinking water is of no consequence in itself. While the secondary effects of dissolved oxygen on water treatment and distribution systems are important, it is beyond the scope of this discussion. Dissolved oxygen is primarily a concern for the viability of aquatic life. The levels stipulated, (Environment Canada, 1979; MOE, 1984a), 4-8 mg/L, have a range that reflects the seasonality of maximum possible dissolved oxygen and the ability of aquatic species to remain productive. In general, the lower limit refers to the warmer weather when the solubility of oxygen is lower but aquatic species are metabolically more active. In cold months a higher dissolved oxygen is desirable balancing higher available concentrations of dissolved oxygen against a slower metabolism.

Dissolved oxygen can be depleted by natural processes in an aquatic environment. The availability of organic matter (e.g.

from pollutant discharges) can encourage biological communities to grow by consuming the organic matter and using dissolved oxygen. A depletion of dissolved oxygen can be indicative of pollutant discharges or perhaps natural inputs of organic matter.

Oxygen is also produced by some aquatic life forms, those based on photosynthesis. In addition to long period variability in dissolved oxygen levels, a diurnal variation of significant proportions is apparent in the sunny months. These factors all mean that the variability in dissolved oxygen results from complex reasons and needs to be carefully considered.

Conductivity

Conductivity is an indicator property of water. Conductivity reflects the total load of dissolved ionizable salts present in the water. It is easily measured with simple resistive measuring devices producing a signal that can be used in process control. As a water quality parameter it signals the observer to consider other parameters to identify the source of the conductivity. Natural waters and all but specially treated process waters exhibit significant conductivity. It is only when its value ranges outside normal range that the source of the conductivity (or lack of it) is a concern. Natural waters like the surface waters in West Lincoln exhibit conductivities of 20-50 $mS.m^{-1}$ (20[illegible]-500 umho/cm) (Environment Canada, 1979).

Total Dissolved Solids

Total dissolved solids is the total material left after evaporating a filtered water sample. It comprises principally the major dissolved species in natural waters, calcium, magnesium, sodium and potassium salts with bicarbonate, sulphate, nitrate or chloride anions. Some dissolved organic matter will report in this parameter as well. Total dissolved solids are estimated from

the conductivity being five times the conductivity in $mS.m^{-1}$ (or half the conductivity in umho/cm) in the dilute range found in natural waters. In Southern Ontario, surface waters with several hundred mg/L of total dissolved solids are routinely encountered.

The criterion for total dissolved solids in drinking water is 500 mg/L(MOE, 1983). This level is based on the poorer taste of highly mineralized waters and the usual correlation of high scaling propensity with waters containing large amounts of dissolved material (often carbonates and bicarbonates).

In general, aquatic organisms select or become highly acclimatized to waters of a specific range of dissolved salts in respect of the total amount of salt and the speciation of the salt load. They are therefore sensitive to changes in the dissolved solids load. Ontario (MOE, 1984a) has established that an effluent should not raise the dissolved solids load by more than 1/3 of the existing concentration. In addition the composition of the salts contributing to the total dissolved load should not change significantly so as to not "alter the overall ionic balance".

Total dissolved solids are also considered as important in the agricultural use of water for livestock watering or irrigation. However levels of concern are in the range 1000-3000 mg/L, much higher than the 1/3 increase necessary to protect aquatic life.

Turbidity

Turbidity is another indicator property of water quality rather than a measure of a specific chemical constituent in water. The material that contributes to turbidity in water tends to absorb various harmful agents from water and protect them from treatment. In drinking water, high turbidity can be associated with viable

bacteria even in the presence of a disinfectant. It may also correlate with the production of chlorination by-products. Turbidity constituents may hold biocides, toxic organics or heavy metals. Tubidity undoubtedly correlates with the efficacy of the most fundamental water treatment practices (i.e. filtration) (MOE, 1983). As a result the provincial drinking water objective is 1 NTU (Nephelometric Turbidity Unit).

Turbidity is, however, also indicative of a viable aquatic community. Acidified lakes often appear highly attractive because of their clarity, in fact, they are dead. The provincial guideline (MOE, 1984a) states that discharges should not change the Secchi disk reading by more than 10%. The Welland River is obviously a fairly turbid watercourse so that a criterion pointing to highly clarified water is not appropriate.

The American Water Works Association (AWWA, 1969) has classified raw water sources relative to their acceptibility as follows:

Turbidity (NTU)	Raw Water (Source) Classification for Treatment in Municipal System
0-10	Excellent
10-250	Good
>250	Poor

The best approach will consider turbidity in light of these various factors; it will not aim to meet one or the other explicitly but will consider the overall impact of effluent turbidity.

Alkalinity

Alkalinity is a fundamental description of overall water composition. By definition it is the measure of a water's ability to neutralize strong acid inputs. In actual usage, when considered in conjunction with the pH, it is used to assess the overall stability of the water with respect to inputs of strong bases, acids and metals. It measures, in most natural systems, the status of the carbon dioxide - bicarbonate - carbonate equilibrium in the systems. It is expressed as the weight of calcium carbonate ($CaCO_3$) equivalent to the observed acid neutralizing ability in the water.

In drinking water, alkalinity is advantageously present in a range from 30-500 mg/L (MOE, 1983). This permits stable operation of water clarification processes and minimizes the potential of corrosion of distribution systems. This is a function then of a treatment imposed on a natural water to facilitate distribution in a municipal system.

Natural systems are more susceptible to changes in alkalinity that destroys the natural buffering capacity. The Ontario objective states that alkalinity must not be decreased by more than 25% (MOE, 1984a). This will ensure that the natural acid balance activity will not be affected beyond the normal range by phtosynthetic activity. Also, natural or man-made inputs of acids, bases or metals will be absorbed by the system (buffered) so that the acid balance will be maintained.

Total Organic Carbon

Total organic carbon is another indicator parameter for general water quality. An analysis for total organic carbon measure the content of man-made and natural carbon containing materials in a water sample. The materials are often distributed or partitioned between the dissolved phase and material suspended in the water. The particulate material is, in part, composed of aquatic life or

their detritus. The dissolved carbon compounds are simpler molecules and in clear waters are the predominate portion of the total organic carbon. Often a parameter called dissolved organic carbon is used to typify water quality. Given the turbid nature of the surface waters in the environment of the OWMC preferred site total organic carbon was the preferred parameter over dissolved organic carbon.

As with turbidity, the total organic carbon is an indicator of water quality. No specific criterion exists for total organic carbon in a natural system to judge water quality. It is perhaps more important that a database be developed for total organic carbon so that trends and abrupt changes can be used as a warning to look elsewhere in the parameters list for the cause. The trends and changes may not be related to any change in the list of toxic organics used in this study. Natural waters contain a variety of organic compounds which are not toxic but contribute to the total organic carbon.

Ontario (MOE, 1983) has set a drinking water maximum desirable concentration (MDC) of 5 mg/L for total organic carbon as a generally safe level which will act as a warning level for related problems. Otherwise innocuous inorganics are known to react with some organics (humic substances) to produce trihalomethanes.

Most of the total organic carbon associated with the particulates would be removed by drinking water treatment processes so the drinking water criteria are not highly relevant to a natural water. It would be expected that high total organic water would require more treatment as is the case for turbidity removal. In general, as a measure of general water quality the important feature for total organic carbon is its "normal" value and a caveat that excursions from this range require explanation.

Alkali Metals: Sodium, Potassium

The alkali metals, sodium and potassium, are among the major cationic components of natural waters and comprise the principal cations of most aquatic organsims. A knowlege of their concentration, in water contributes to the fundamental understanding of the waters composition.

In an agricultural area, major contributors to alkali metal content would include agricultural run-off (animal waste and fertilizers), possible briny groundwater inflows, road run-off and sewage system effluents. Sodium would be expected to predominate except where fertilizer run-off contributes significantly to potassium levels.

In drinking water sodium is not harmful to most individuals except insofar as it contributes to total dissolved solids and overall salinity which may affect palatability. However Ontario (MOE, 1983) recognizes the hypersensitivity of individuals with cardio-vascular disease to evaluated levels of sodium and requires a notice be given to local Medical Officers of Health when sodium exceeds 20 mg/L in drinking water.

For the natural environment the principle of maintaining the ionic balance is perhaps most crucial. Rapid changes in the total contribution of sodium and potassium to water quality and their relative abundances should be guarded against.

Water used for irrigation needs to be evaluated in relation to the balance between sodium content and alkaline earth metal (Ca, Mg) content. The sodium adsorption ratio (SAR)

$$SAR = (\text{Equivalents Na}) \Big/ \sqrt{\frac{(\text{Equivalents Ca + Mg})}{2}}$$

should ideally be <4 to keep the adsorption of sodium by plants within acceptable ranges. At SAR >7 the soil composition becomes problematic due to reduced permeability.

Alkaline Earths: Calcium, Magnesium

The alkaline earth metals, calcium and magnesium, are the other major contributors to the cationic composition of natural waters. In the Welland River watershed the basal rock is limestone in various formations and capable of contributing heavily, through weathering, to the make-up of the dissolved ionic components of these waters. Calcium, and to a lesser extent magnesium, as their oxides, lime and magnesia are also widely used industrial and agricultural chemicals and are sources of calcium and magnesium ions.

These metals principally define water hardness. Excessively hard waters are aesthetically displeasing as drinking water because of taste and staining. Acceptable hardness ranges for drinking water have been suggested by Health and Welfare Canada (HWC) (HWC, 1980) as follows.

Good	- 80-100 mg/L	as $CaCO_3$
Poor	- >200 mg/L	as $CaCO_3$
Unacceptable	- >500 mg/L	as $CaCO_3$

As with many other of these gross water quality parameters the optimal concentration lies in a range well above trace quantities but not excessively high. The natural environment in West Lincoln produces naturally hard water and as stated above, discharges should not alter the natural water quality so as to destroy the ionic balance of the water. Also, drinking water advantageously should contain a balance of bicarbonate alkalinity and calcium hardness to protect distribution piping from excessive corrosion or encrustation.

Livestock such as cattle will tolerate calcium levels up to 1000 mg/L although at these levels magnesium should be controlled below 700 mg/L (MOE, 1984a).

Halides: Fluoride, Chloride and Bromide

The halides are present naturally in surface water in concentrations dependant on local geological conditions and human activity. Chloride is a major anionic species in most surface waters so its concentration is fundamental to the understanding of the water's composition. It originates from natural brines, agricultural activities, sewage treatment and a variety of industrial processes. The other halides are usually present in ratios to the chloride that are reasonably fixed when base flow conditions exist, (chloride/fluoride = 32, chloride/bromide = 1400) (Environment Canada, 1979). Departures from these ratios are expected when run-off or industrial discharges overwhelm the natural contributions. In fact, the specific use of fluorides and/or bromides in certain industrial processes, the waste therefrom and the high solubility of their salts makes their appearance in natural systems significant when natural background levels are exceeded.

The only concerns raised about fluoride by all governmental agencies reviewed are fluoride levels in drinking water and water used for livestock watering or irrigation. The most stringent controls are placed on fluoride levels in drinking water. Drinking water criteria levels for fluoride are set at 1.2 mg/L (MOE, 1983) and 1.5 mg/L(HWC, 1978). It must be noted, however, that the 1.2 mg/L criterion is set as a control over fluoride levels in fluoridated drinking water. High levels of fluoride (5 mg/L) in water used for drinking purposes may result in osteosclerosis (thickening of the bone) in adults. Dental fluorosis, brown discolouration, pitting and crumbling of the teeth, has also been noted by the United States Environmental Protection Agency (USEPA) as a concern from elevated fluoride levels in water. The maximum acceptable concentration for naturally occurring fluoride is 2.4 mg/L (MOE, 1983). Fluoride levels in surface water are generally much lower than 1.2 mg/L. However, fluoride cannot be easily removed from water. Therefore, surface waters that could be used as a drinking water sources should contain less than 1.2 mg/L.

Chlorides in drinking water cause aesthetic problems (taste) at levels above 250 mg/L (MOE, 1983).

Bromides are readily oxidized by chlorine in water treatment plants. The resulting bromine oxidant chemistry produces bromomethanes and brominated organics in fashion and effect similar to chlorine. Some aspects of bromine chemistry make this route to halomethanes and haloorganics (e.g. hydrogenated phenols) more readily available and thus poses a problem. Natural levels, three orders below chloride, would be unlikely to cause a problem, however the presence of bromide in surface waters may lead to enhanced halomethane formation in drinking water.

Sulphate

Sulphate is also a major contributor to the anionic component of the dissolved ionizable salts in natural water. It comes mainly from some groundwaters, agricultural processes (fertilizers), industry and domestic sewage.

In drinking water, aesthetic (taste) problems arise at sulphate levels above 500 mg/L (MOE, 1983). As an industrial supply, water with high sulphate will cause scaling with calcium ions.

As with other major species the importance of maintaining the ionic balance in natural receiving systems is stressed. Sulphate can often be used in a comprehensive database to develop evidence for the contribution of diverse sources to a natural water because it is a conservative ion and often poorly attenuated by natural processes.

Phosphate and Nitrate

These two anions complete the general chemical composition of natural surface waters. In large bodies of water they are generally present at low concentration because of natural processes assimilating them. These effects and limits are discussed under "Nutrients" in the following section. They could be important in the detailed understanding of the water chemistry because of inputs from agriculture and domestic sewage systems.

NUTRIENTS

Ammonia

Ammonia at modest concentrations is not a concern for human consumption. HWC has suggested a level of 0.5 mg/L as a screening level for ammonia in drinking water (HWC, 1978). Ammonia may encourage the formation of nitrite and nitrate by acting as a bacterial nutrient. This concern is evaluated in considering the other parameters.

The principal environmental concern over ammonia is its effect on aquatic species, mainly fish. The MOE criterion 0.02 mg/L is for the unionized part of the ammonium/ammonia-conjugate acid/base pair (MOE, 1984a). The analysis for ammonia in water totals the nitrogen present in the ammonium form and the ammonia form. The guidelines for ammonia provide for a calculation which will enable unionized ammonia to be calculated from the total. As an approximation, at pH 9.2, the ammonia nitrogen is equally distributed between the ammonia and ammonium species. For the calculation to be totally accurate, one must take into account temperature and the total dissolved salt in the water.

The ammonia is said to be absorbed into the blood stream of fish so that it interferes with the uptake of oxygen. The fish then suffocate (Environment Canada, 1979).

Total Kjeldahl Nitrogen

Total kjeldahl nitrogen is a measure of the total nitrogen content of a water sample for nitrogen in the -3 oxidation state (ammonia, organic amines including aliphatic amines, amino acids, protein and other polypeptide systems). When considered along with ammonia nitrogen, by difference, it is a measure of the organically bound nitrogen. Organic nitrogen arises in surface water from living organisms and their waste products. In

agricultural communities sources include animals wastes, domestic sewage effluents and fertilizer run-off.

Levels of organic nitrogen in nutrient rich waters like the Welland River can be expected to be significantly above background levels of 0.01 mg/L found in pristine environments (Environment Canada, 1979). Organic nitrogen concentrations will be dynamic and seasonal because organic nitrogen is readily available for uptake by aquatic plants and organisms. Organic nitrogen content is not a concern as a persistent contaminant. In drinking water, organic amines consume chlorine producing foul-tasting chloramines. It has been observed (MOE, 1983) that waters with 0.15 -0.2 mg/L organic nitrogen are subject to consumer complaints because of taste. Conventional treatment will remove some organic nitrogen although smaller molecules will pass through treatment largely unchanged.

Total Phosphorus, Phosphate

Phosphorus is present in natural surface waters primarily as the oxyanion, phosphate. The ultimate form of phosphorus is dependent on the pH of the aqueous system, the source and history of the contributing species and the presence of other mineral components capable of interaction with phosphates to form complex species. Species exist in solution as colloidal dispersions or suspended matter. The base species, phosphate, predominantly present as the HPO_4^{2-} species, contributes to the gross composition of aqueous systems. In other forms phosphorus is present in more complex forms but not so complex as not to be available for the support of aquatic life.

Phosphorus is not particularly toxic to aquatic or human life. It promotes however the growth of nuisance algae when present at concentrations above 0.1 mg/L and sufficient nitrogen is also present. Environment Canada and MOE (Environment Canada,

1979; MOE, 1984a) have suggested ambient phosphorus concentrations, below which, nuisance algal growths would not be a problem

0.03 - 0.10 mg/L	-	flowing streams
0.05 mg/L	-	waters flowing into lakes/reservoirs
0.02 - 0.025 mg/L	-	lakes, reservoirs
<0.01 mg/L	-	"high level of protection against aesthetic deterioration" in lakes.

Nitrate

Nitrate in surface water is of concern if water is used as a drinking water source. Nitrate is also recognized as a nutrient that can stimulate the growth of algae and other organisms. No criteria were provided in the documentation reviewed to determine when the nutrient effects of nitrate become problematic. Water to be used as a human drinking water source should contain less than 10 mg/L nitrate when analyzed as N (nitrogen) or 45 mg/L when analyzed as NO_3 (nitrate). It is recognized that raw surface water will not be used untreated as a drinking water source. Nitrates cannot be removed from water by traditional water treatment methods. Highly specialized treatment is required. Therefore, raw surface water should also contain less than 45 mg/L nitrate analyzed as NO_3.

The reason for this criteria is that acute exposure to greater than 45 mg/L NO_3 in drinking water may cause methemoglobinemia in infants (MOE, 1983). This possibly fatal disease is caused by the fact that infants have intestinal bacteria which reduce nitrate to nitrite but no bacteria to convert nitrite to nitrogen. The resultant elevated nitrite levels react with iron in the hemoglobin. Hemoglobin is altered so that it is unable to transfer oxygen. Thus, the tissues become oxygen starved.

Not all infants are affected by nitrate levels greater than 45 mg/L as NO_3. However, studies have shown that there is no risk of infantile methemoglobinemia at levels below 45 mg/L as NO_3. Therefore, nitrate concentration in surface waters should be carefully watched.

Environment Canada has also set a criterion for nitrate levels in water used for livestock watering (Environment Canada, 1979). This criterion is based on the same concerns discussed above and has been set at a level 10 times higher than the level of concern for human drinking water. Therefore, if the criterion for human drinking water is met there will be no concern over the use of water for livestock watering.

Nitrite

As outlined above, nitrate is produced from nitrate in the natural nitrification-denitrification cycle. As the causative agent identfied in the concern expressed about nitrate it is expected that a more stringent level be given for nitrate. All drinking water documents set a level of 1 mg/L nitrite (as N) (HWC, 1978; MOE, 1983) reflecting the more direct toxic effect from ingesting water containing nitrite rather than nitrate.

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is a measure of the biologically oxidizable material in a natural water or a wastewater. It is measured over a prescribed 5 day period at a controlled temperature of 20°C. It reflects the consumption of oxygen by microflora innoculated into the test solution. Oxygen is consumed in converting organic material to stable inorganic species. The five day test measures essentially the oxidizable carbon content of the water and will be subject to any interference occasioned by the presence of toxics in the water.

BOD can be taken as a measure of organic contamination of a water. The treatability of wastewater by conventional aerobic digestion can be assessed by measuring the BOD. Sources of oxidizable organic material are natural sources (decay and animal waste) and agricultural wastes such as those expected in an agricultural setting. BOD is an indicator parameter. Environment Canada (Environment Canada, 1979) considers any BOD level above 10 mg/L as indicative of polluted waters while waters with levels below 4 mg/L are called 'reasonably clean'.

BACTERIOLOGICAL

Bacterial Counts

Four parameters grouped in this category provide the primary indicators of surface water quality in small river and drainage systems such as those being considered in this study. The criteria for drinking water for two specific counts of coliforms (fecal and fecal streptococci) are zero in recognition that these coliforms originate in the gut of warm blooded animals and as such are indicators of pollution by human or animal waste. The total coliform count is indicative of fecal pollution plus soil runoff. This count covers a range of less threatening organisms so less stringent levels are permitted, although never in two consecutive samplings (MOE, 1983). The background count or so-called standard plate count identifies a range of aerobic bacteria and facultative anaerobic heterotrophic bacteria which reflect on the overall biological activity in the water supply. These are essentially non-threatening bacteria used to monitor general water quality degradation in water supply systems.

Bacterial levels also impact the recreational use of the watercourse. Certain diseases of the gastrointestinal tract, eyes, ears, nose, throat and skin may be caused by bacteria and can be contacted by people swimming in the water. HWC and the Ontario MOE have established recreational water quality guidelines for bacterial counts.

HWC have established that for recreational use, the geometric mean of not less than five samples should be less than 200 fecal coliforms per 100 mL (HWC, 1983). They recommend resampling if the fecal coliform count exceeds 400 per 100 mL.

They have set no limits for total coliform or fecal streptococci counts. The Ontario MOE reports that a potential health hazard exists for recreational users if the geometric mean for a series of samples exceeds 100 fecal coliforms per 100 mL and that water quality is impaired for recreational use if total coliforms exceed 1000 per 100 mL (MOE, 1984a).

The fecal coliform and fecal streptococci counts can be used to indicate the source of fecal pollution. If the fecal coliform count predominates the bacterial source is human and if the fecal streptococci predominates the source is animal (specific ratios involving geometric means are used).

TRACE CONSTITUENTS

Arsenic

Arsenic is a trace consitutent of natural waters arising naturally from weathering of rocks where arsenic may be found both in the elemental state and combined with oxygen. Man-made inputs arise

from fossil fuel combustion, smelting and roasting of ores, miscellaneous manufacturing uses and herbicides and pesticides. Arsenic in the aerobic aquatic environment is present in the As(V) state. Under reducing conditions the As(III) state predominates and in sediments and strongly anaerobic environments, arsenic-nitrogen and arsenic-sulphide compounds can exist. In these lower oxidation states organo-arsenic compounds are possible and many contribute to environmental transport.

Arsenic in the +5 state is not readily absorbed by humans and is readily eliminated. However As(III) can form readily in food stuffs and water and can be ingested by humans. Evidence is fairly well accepted that excessive arsenic ingeston can cause or promote skin cancer and peripheral vascular dysfunction (NRC, 1983). A drinking water level of 50 ug/L is thought to strike a balance between exposures responsible for skin cancer occurences in Taiwan and the essentiality of arsenic in the human diet. This assumes that water accounts for 10% of arsenic ingestion with the majority of the rest of the exposure through food.

Arsenic exposure levels developed by the USEPA for information only under the Clean Water Act are substantially lower based on cancer risk extrapolations (USEPA, 1980). Lifetime exposure to water at 2.2 ng/L as a source of drinking water and a source of seafood poses an increased cancer risk of one in 10^6 (USEPA, 1985). However, under the 1986 amendments to the U.S. Safe Drinking Water Act the 50 ug/L level for drinking water is being supported.

Arsenic in the aquatic environment interacts with life forms at various species levels. As the anaerobicity increases from the water column to sediments, the form and mobility of arsenic changes. In the lower oxidation states, organoarsenic compounds

play an increasing role; bioaccumulation in organisms is apparent although biomagnification does not appear to occur. Levels of concern raised by USEPA are tied to length of exposure (USEPA, 1980). They suggest levels of 190 ug/L for a 4 day average once in a three year period for the protection of acquatic life.

In Ontario protection for crops through irrigation and livestock watering is achieved by levels of 100 and 200 ug/L respectively (MOE, 1984a).

Cadmium

Cadmium is an extremely toxic metal which is of general concern in all water uses. The greatest concerns for cadmium levels in water are for the use of water as drinking water and the impact of cadmium on aquatic species. For the purposes of this background water quality assessment, the most important of these impacts is the impact of cadmium on aquatic species. This is because aquatic species are impacted by cadmium at a much lower level than humans are impacted by drinking the water. As well, there is a much higher probability that aquatic species can be impacted by elevated cadmium levels.

The MOE, Environment Canada and the International Joint Commission (IJC) have all set their criteria for the Maximum Allowable Concentration (MAC) of cadmium for the protection of aquatic species at 0.2 ug/L. The National Research Council (NRC, 1979) has found that cadmium pollution problems occur mosty in rivers, lakes and coastal waters located in or near industrialized areas. The acute toxicity of cadmium to aquatic species, particularly molluscs, crustaceans and fish is encountered at low concentration. As well, as little as 1 ug/L of cadmium has been found to interfere with reproduction in brook trout. The toxic effects of cadmium on aquatic species vary with species and

exposure time. As well, the presence of other heavy metals, such as zinc or copper, increase cadmium's toxicity. All these factors have been combined by Canadian governmental agencies to set a criterion for the protection of aquatic species at a maximum cadmium concentration of 0.2 ug/L.

The USEPA has developed guidelines for the protection of fresh water aquatic life (USEPA, 1985) which are dependent on water hardness. They are:

Hardness (as $CaCO_3$) (mg/L)	Cadmium Levels	
	24h Average (ug/L)	Any Time (ug/L)
50	.012	1.5
100	.025	3.0
200	.051	6.3

Cadmium is also toxic to man, mainly through ingestion. As a result, a MAC for cadmium in drinking water is 5 ug/L (MOE, 1983). As can be seen this level is an order of magnitude greater than required to protect aquatic species. As well conventional water treatment processes can successfully lower cadmium levels in raw water. Therefore, the impacts of cadmium on aquatic species in surface water are of greater concern than those of man.

Chromium

Chromium is a relatively rare element in natural surface water although trace amounts are known to be essential (HWC, 1980). It occurs naturally, from weathering of trace amounts in rock. In industrialized areas chromium is used extensively in alloying, plating, chemical process oxidations, fungicides, pigments and

glazing. The chemistry involves principally the Cr(III) and Cr(VI) species. Cr(III) is the principal species in natural aquatic systems and exhibits low solubility such that it would be expected to be associated with suspended material. In biologically active forms it is expected chromium would be complexed with organic species. Cr(III) is generally non-toxic and most of the concern is associated with the Cr(VI) species. Cr(VI) can be formed by oxidation in naturally aerated waters and more readily by chlorination in water treatment processes. The amount of oxidation is limited by the heterogeneous nature of the reaction of insoluble Cr(III) and the removal of hydrated Cr(III) during water treatment.

Chromium(VI) is responsible for a variety of effects the most serious of which is cancer in the gastrointestinal tract through ingestion and lung cancer through respiration (HWC, 1980). There is controversey (NRC, 1977) as to whether any non-occupational exposures leads to cancer. The criteria established do not differentiate between Cr(III) and Cr(VI). The criteria for drinking water is 50 ug/L being 1% of the no observed effect level (NRC, 1977).

For the protection of aquatic life the criterion is related to hardness (USEPA, 1985) and for the West Lincoln environment levels of Cr(III) in the 100-400 ug/L range are suggested. For Cr(VI) a much lower criterion is suggested (USEPA, 1985) of 11 ug/L.

Both criteria are for single 4 day exposures in a three year period. These levels are comparable to the Ontario levels for aquatic environmental protection of 100 ug/L (MOE, 1984a).

It is noteworthy that there appears to be a move to higher chromium levels in the USEPA work following the 1986 SDWA amend-

ments. Proposed RMCL (Recommended Maximum Contaminal Level) for drinking water for chromium is 120 ug/L.

Cyanide

Cyanide is found in trace quantities in most environmental water samples. It can be produced by natural process and is widely used in industry (e.g., plating). Industrial processes like coke production and combustion also produce cyanide. Cyanide has well documented acute toxic effect in humans and fish where it blocks the oxygen carrying ability of the blood.

A human toxic dose could be received in 2 L of water at 5 mg/L (HWC. 1980). The drinking water standard provides a safety margin of 25 in setting the level at 200 ug/L (MOE, 1983).

Fish appear to be much more sensitive, reacting acutely at concentrations as low as 200 ug/L (Environment Canada, 1979). For protection of aquatic life therefore Environment Canada (Environment Canada, 1979) and MOE (MOE, 1984a) recommend that ambient levels not exceed 5 ug/L. This level has been affirmed more recently by the USEPA (USEPA, 1985).

Lead

The concern over lead is for both human consumption and for the effects on aquatic life. Much of the work on lead has been focused on humans but given the long noteriety of lead, a vast body of information exists on its effect on aquatic and other fauna. Lead is not an essential element in the human metabolism. It has been implicated in a number of disorders affecting blood, cardiovascular system, nervous system, kidneys and the reproductive system. Special attention is given to children where mental disorders, ranging from hyperactivity to retardation, are observed.

The pathway of lead ingestion varies and absorption is a function of age. In consideration of a variety of evidence the level is set at 0.05 mg/L for drinking water. It is noteworthy that lead from drinking water probably accounts for only 1/4-1/3 of our intake of lead.

For a range of aquatic life, deliterious effects of lead are noted in the literature. Lead, like mercury, can methylate making it more available for uptake and thus is a more toxic form of the metal. The toxicity is affected by the hardness of the water (complexing of lead and carbonate) so that the levels of concern vary with harndess. The USEPA (USEPA, 1985) criterion for protection of freshwater aquatic life in hard water like that found in West Lincoln, is 20 mg/L. The MOE (MOE, 1984a) suggests a similar level at a corresponding water alkalinity.

Mercury

Mercury is a trace element in the natural environment; natural levels in surface water in West Lincoln are expected to be vanishingly small. Observed levels may be attributable to man-made sources. Mercury has been used extensively in industry in the past, notably in the production of chlorine and caustic soda. This use has been curtailed and miscellaneous industrial uses in the electrical industry, paint manufacture and dentistry remain. Mercurial fungicides have been used in agriculture and industrial settings.

In the natural environment mercury distributes between Hg(0), Hg(I) and Hg(II). These species are involved in complex equilibria in water with various forms predominating under various conditions. In sediments, sulphides and methylmercury compounds form and the latter are highly significant in interactions with the biota. Methylmercury compounds are much more highly absorbed

by organisms. They are generally more toxic and bioaccummulate in organisms and in the food chain.

Mercury has no known beneficial interaction with humans or aquatic organisms. Mercury in humans accumulates in kidneys and the nervous system leading to neurological disorders and kidney damage. Damage to fetuses and children are accentuated because of their enhanced sensitivity in their maturing neurosystems. The onset of neurological problems in humans is said (HWC, 1980) to occur at an ingestion rate of 0.004 mg/kg/day. In a 70 kg person, allowing 10% contribution from water, this translates to a drinking water concentration of 4 ug/kg/day x 70 kg/person x 10% / 2 L/person day = 10 ug/L. A 10x safety factor is suggested resulting in a drinking water MAC of 1 ug/L.

Environment Canada and the MOE (Environment Canada, 1979; MOE 1984a) have set ambient water quality objectives at 200 ng/L in recognition that mercury bioaccumulates and is toxic to fish. This level is at the detection level for mercury (HWC, 1980) so it is preferable that mercury be absent.

The USEPA have suggested levels of 12 ng/L to protect fresh-water aquatic organisms (USEPA, 1985) and 144 ng/L in ambient water to protect humans (USEPA, 1980) using this water as a source of drinking water and aquatic food. These are extrapolated exposure levels below conventional detection limits for mercury.

Sulphide

Sulphide sulphur is a naturally occurring form of the element found when anaerobic conditions develop in decaying material. It would be expected to be found naturally in sediments and in agricultural and domestic sewage run-off. Industrial processes using sulphur have the potential of emitting sulphide sulphur from

a variety of industrial processes like metal removal from process wastewaters.

Sulphide in water exists in equilibrium with hydrogen sulphide which produces a highly offensive smell. Sulphide sulphur is acutely toxic to humans in relatively low doses but humans are able to detoxify small amounts and usually avoid larger amounts because of the offensive odour. A drinking water level of 50 ug/L is about at the threshold of odour in humans. This is well within the level at which humans can detoxify it and is thus used as the drinking water criterion.

Environment Canada (Environment Canada, 1979) and the MOE (MOE, 1984a) have suggested that a long-term level of 2 ug/L is required to protect aquatic organisms, although fish do not seem to be harmed by short-term exposures at this level.

Aluminum

Aluminum is a widely occurring natural element being a major constitutent of rock and soils usually present in highly insoluble forms. Weathering leads to aluminum concentrations in natural waters although in the normal pH range aluminum will be present in an insoluble suspended form. Recently, concern has been raised for soluble aluminum toxicity in acid stressed environments as one of the mechansisms of aquatic degradation from acid precipitation. Aluminum is widely used in the water treatment industry and discharge to the raw water source is often used as a disposal method. Aluminum is also used in a variety of domestic cleansing and food products.

Aluminum causes taste problems in drinking water and can result in interference in the water distribution systems. Ontario (MOE, 1983) suggests a limit of 0.1 mg/L to avoid precipitation in the distribution system. The World Health Organization (WHO),

(WHO, 1984) recommends a level of 0.2 mg/L to avoid taste problems.

In the aquatic environment a tentative limit of 0.1 mg/L has been suggested by Environment Canada (Environment Canada, 1979).

Copper

Copper is an aesthetic concern in drinking water. The criterion for drinking water is 1 mg/L (HWC, 1980; MOE, 1983). However, of far greater concern are the impacts of copper on aquatic species and animals through livestock watering. Aquatic species are by far the most susceptible to copper. The toxicity of copper to aquatic species varies with the speciation of copper and the physical/chemical characteristics of the water: hardness, temperature, turbidity. Copper has been found to affect the reproduction, respiration and growth of many Canadian fish species. As a result, a criterion for the protection of aquatic organisms has been set at 5 ug/L (Environment Canada, 1979).

The USEPA (USEPA, 1985) has more recently assessed the toxicity of copper to freshwater species. The long term average concentration for waters in the hardness range found in West Lincoln is in the 10-20 ug/L range.

Iron

The levels of concern presented for iron are similar for its impacts on drinking water and its effects on aquatic species. The MAC of iron for both of these receptors is 0.3 mg/L. However, the impacts of iron on drinking water are purely aesthetic. Iron, in high concentration, (>0.3 mg/L), may precipitate in drinking water, cause an astringent taste, or even promote the growth of bacteria in water pipes. These problems are all aesthetic and none are health related. As well, iron tends to be associated

with sediments and, as such, elevated raw water iron concentrations are easily removed by high efficiency filtration during water treatment.

At the same concentration identified above, 0.3 mg/L, iron salts in water have been found to precipitate on contact with air. This precipitated iron may produce adverse effects on aquatic organisms. The nature of these effects has not been documented.

Manganese

Manganese is a common metal in the natural environment occurring with iron and exhibiting similar chemistry. It is an essential element for plants and animals and is a constituent of minerals that compose soils and sediments.

Manganese exhibits a number of oxidation states in nature. Mn(II) and Mn(IV) are the most common; Mn(IV) compounds are largely insoluble. In anaerobic situations, manganese is present as more soluble manganous salts and readily enters drinking water systems often passing through treatment plants unaltered. When exposed to aerobic conditions, manganese oxidizes to insoluble oxides which deposit on porcelain surfaces and in pipes. As such, it presents an aesthetic problem to the householder and a distribution system problem for the municipality should precipitate build-up and restrict the water flow in distribution systems. A level of 50 ug/L is set for drinking (MOE, 1983) water because it is thought it will avoid these problems and other problems associated with bad taste in drinking water.

Zinc

Zinc is a widely occurring metal in natural and industrial processes. It is an essential element in animal and plant

nutrition. Its chemistry keeps ambient concentrations at low levels but in drinking water, plumbing materials can contribute to much higher levels.

Zinc in the 10's of mg/L range of concentration imparts an astringent taste to water and creates a cloudy appearance because of precipitation at drinking water pH's. To protect against these aesthetic problems, a concentration of 5 mg/L is set as an objective (HWC, 1980; MOE, 1983).

For the protection of freshwater aquatic life the USEPA has suggested (USEPA, 1985) a zinc water quality criterion in the 300 mg/L range for waters with hardness typically found in West Lincoln.

Phenols

See Section on chlorophenols.

PRIORITY ORGANICS: ACID EXTRACTABLES

Phenol and Chlorphenols

Chlorophenols are commonly used as biocides, fungicides and wood preservatives or as intermediates in biocide manufacture (MOE, 1984b). In this study 9 chlorophenols were investigated:

2-chlorophenol
p-chloro-m-cresol
2,4-dichlorophenol
2,3,4-trichlorophenol
2,4,5-trichlorophenol
2,4,6-trichlorophenol
2,3,4,5-tetrachlorophenol
2,3,5,6-tetrachlorophenol
pentachlorophenol

These chlorophenols are all extensively used in Canada and are ubiquitous in the environment. They have been identified in Canada in surface water, snow, sediments, agriculture produce, aquatic species and in man (Environment Canada, 1981b). Chlorophenols are produced in drinking water as a result of the chlorination of phenolic compounds (MOE, 1983).

Phenol, itself is used to produce the chlorophenols and has very similar toxic and organoleptic (taste and odour) concerns. As such, phenols are included in this discussion.

Chlorophenols are an aesthetic concern in drinking water. They cause unpleasant tastes and odours at low concentration. WHO has determined that the taste and odour threshold concentration for chlorophenols in drinking water is 1.0 ug/L (WHO, 1984). WHO has therefore set criteria for acceptable levels of chlorophenols in drinking water at 0.1 ug/L, 10 times lower than the taste and odour threshold. WHO has also noted that 2,4,6-trichlorophenol is a possible human carcinogen and pentachlorophenol can damage kidney and liver and is toxic to fetuses. They have set a guideline for 2,4,6-trichlorophenol in drinking water at 10 ug/L as a result of its carcinogenic properties (WHO, 1984). However, they also note that 2,4,6-trichlorophenol may be detectable by its taste and odour at 0.1 ug/L.

Pentachlorophenol, a common wood preservative, as stated above is toxic to humans both occupationally and in drinking water. It can damage the liver and kidneys and has been found, in animal studies to be toxic to fetuses (WHO, 1984). Many studies have also shown (Environment Canada, 1981) that pentachlorophenol (PCP) is often contaminated with polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs). This is due to the reaction conditions required in the latter chlorination

stage of the PCP manufacturing process (Environment Canada, 1981). This contamination of PCP with PCDDs and PCDFs has not impacted the manner in which criteria for PCP levels in water have been set. It has, however played a role in the diminishing of the permissible uses of PCP in Canada. WHO has set a guideline for PCP in drinking water at 10 ug/L. This is based on the toxic effects of PCP to humans and is again 100 times higher than the criterion set to limit the taste and odour effects of chlorophenols. HWC (MOE, 1983) has not set drinking water criteria for individual chlorophenols. Drinking water standards for phenols have been set at 0.3 mg/L (USEPA, 1980) and 0.002 mg/L (MOE, 1983), to control undesirable taste and odours in chlorinated drinking water - due to the production of chlorophenols.

Chlorophenols impart an unpleasant taste to fish and other aquatic biota (MOE, 1984b). For mono and dichlorophenols this is the predominant concern. MOE has set surface water criteria at 7 ug/L for monochlorophenols and 0.2 ug/L for dichlorophenols to prevent flavour impairment in fish. Tri-, tetra- and pentachlorophenols are acutely toxic aquatic organisms (MOE, 1981). As well, tetrachlorophenols and pentachlorophenol are persistant in the environment. MOE has set surface water criteria of:

- trichlorophenols - 18 ug/L
- tetrachlorophenols - 1 ug/L
- pentachlorophenol - 0.5 ug/L

based on these acute toxicity concerns (MOE, 1984b). Phenol also imparts an unpleasant flavour to fish and MOE (MOE, 1984a) has determined that phenol concentrations in surface water should not exceed 1 ug/L to protect against this.

A summary of water quality criteria suggested by the USEPA (USEPA, 1985) are given below for these compounds.

	Human Health ug/L	Freshwater Aquatic ug/L
phenol	3500	2560
2-chlorophenol	-	4380
p-chloro-m-cresol	-	-
2,4-dichlorophenol	3800	365
2,3,4-trichlorophenol	-	-
2,4,5-trichlorophenol	2600	-
2,4,6-trichlorophenol	1.2	-
2,3,4,5-tetrachlorophenol	-	-
2,3,5,6-tetrachlorophenol	-	-
pentachlorophenol	1010	3.2

* 1/1 000 000 cancer risk.

With the exception of 2,4,6-trichlorophenol which is a suspected carcinogen, the human health effects appear to be poorly supported by research data. The effects for taste as outlined above are significantly lower and are used for criteria in this study.

Nitrophenols

The nitrophenols included in the list of parameters in this study are:

2-nitrophenol
4-nitrophenol
2,4-dinitrophenol
4,6-dinitrophenol
dinitro-o-cresol

Mononitrophenols are used as chemical intermediates in the production of a variety of industrial chemicals from dyes, to pharmaceuticals and pesticides. 4-nitrophenol is the more important mononitrophenol because of the amount produced and the environmental fate of related chemicals (USEPA, 1980). Important

insecticides, the parathions, degrade to this nitrophenol in the natural environment and it is used itself as a fungicide.

Dinitrophenols are used similarly as industrial chemical intermediates with 2,4-diniltrophenol being the predominant chemical in use. They were identified as problematic over 50 years ago through side effects of therapeutic doses of dinitrophenols used as weight loss drugs.

The nitrophenols are acutely toxic at moderate doses in man and other animals (NRC, 1977). At chronic levels they cause cataracts and other sublethal effects. Based on limited data with concomitant high safety factors suggested no-adverse-response-levels for drinking water have been given by the U.S. National Academy of Science (NRC, 1977) as follows:

mononitrophenols - 290 ug/L
dinitrophenols - 70-140 ug/L

The USEPA (USEPA, 1980) assessed dinitrophenols at a similar 70 ug/L level for ambient water quality where water was used for drinking and a source of edible fish. Previously the USEPA suggested (USEPA, 1985) similar but more extensive levels for these componds. They included a suggested level of 13.4 mg/L for dinitro-o-cresol for a similar exposure route.

There is limited data on sensitivity to aquatic organisms. The USEPA has reported (USEPA, 1980) levels of 150-230 ug/L as possibly affecting at least some aquatic plants or animals.

2,4-Dimethylphenol

2,4-Dimethylphenol (2,4-DMP), or 2,4-xylenol, is one of five isomers of dimethyphenol. It is naturally occurring and is derived from petroleum or coal tars. 2,4-DMP is used in the manufacture of a wide variety of chemical substances, including

pharmaceuticals, plastics, solvents, disinfectants, insecticides and dyestuffs.

2,4-DMP is slightly water soluble and there are reports of its presence in drinking water (Sittig, 1981). Data have indicated it to be toxic to certain species of aquatic life at concentrations as low as 2.12 mg/L (USEPA, 1980, 1985). There is evidence that 2,4-DMP is a topical cocarcinogen. However, due to insufficient data, water quality criteria have not been established.

As with other phenol derivatives, 2,4-DMP can cause taste and odour problems. The USEPA has estimated a concentration level of 0.4 mg/L for the control of undesirable taste and odour (USEPA, 1980, 1985).

PRIORITY ORGANICS: BASE/NEUTRAL EXTRACTABLES

Phthalates

Phthalates are the esters of 1,2-benzenedicarboxylic acid (phthalic acid). They are prepared by reacting phthalic acid with various alcohols. The group includes the following compounds:

di-2-ethylhexylphthalate (DEPH)
dibutylphthalate (DBP)
diethylphthalate (DEP)
di-iso-decylphthalate (DIDP)
di-iso-octylphthalate (DIOP)
dimethylphthalate (DMP)
dihexylphthalate (DHP)

Their main use is as plastizers to impart flexibility in many plastic products. The most widely used plastizer is DEPH. They

are also used in cosmetics, rubbing alcohol, insect repellant, and textile and tablet coatings (HWC, 1980).

Humans are exposed to phthalates on a daily basis due to the widespread use of plastics. Some drinking water distribution systems use plastic pipes and many foods are wrapped in plastic. They enter surface and ground water via various industrial effluents. Phthalates are also present in landfill leachate and emissions from municipal incinerators because of the large quantities of plastic materials in solid wastes.

Phthalates are not very water soluble and being lipophilic (i.e. tend to dissolve in fatty matter) they tend to bioaccumulate. Lipid affinity and therefore bioaccumulation increases with increasing molecular weight. However, HWC (HWC, 1980) reports that once in animal tissue, phthalates are not persistent. Therefore, phthalates are not as much of an environmental concern as other more persistent organics. This is reflected in the higher criteria established for phthalates.

It is generally accepted that phthalates have a very low order of toxicity. Until recently they were not believed to be carcinogenic (HWC, 1980). However, the National Academy of Science (NRC, 1986) now feels that there is evidence that DEPH promotes cancer.

The USEPA (USEPA, 1980, 1985) has suggested ambient water quality criteria for four of the phthalates. These are based on the protection of human health from the effects of these compounds through ingestion of contaminated water and aquatic organisms. The criteria are:

DEPH - 15 mg/L
DBP - 34 mg/L
DMP - 313 mg/L
DEP - 350 mg/L

For the protection of freshwater aquatic organisms the USEPA (USEPA, 1980, 1985) has suggested a level of 3 ug/L may be prudent.

Because of the bioaccumulation potential of phthalates the MOE (MOE, 1984a) has set objectives of 0.004 mg/L for DBP, 0.006 mg/L for DEPH, and 0.002 mg/L for other phthalates for the protection of the aquatic environment.

Chlorobenzenes

Chlorobenzenes are primarily used as chemical intermediates in the manufacture of phenols, and dyes. They are also commonly used as solvents, pesticides, electrical dielectric fluids and deodorants (MOE, 1984c). Twelve chlorobenzenes are being assessed in this study:

chlorobenzene
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
1,2,3-trichlorobenzene
1,2,4-trichlorobenzene
1,3,5-trichlorobenzene
1,2,3,4-tetrachlorobenzene
1,2,3,5-tetrachlorobenzene
1,2,4,5-tetrachlorobenzene
pentachlorobenzene
hexachlorobenzene

Chlorobenzenes are widely used in Canada, however, none are manufactured here (MOE, 1984c). The mono- and dichlorobenzenes are volatile and are used extensively as solvents (MOE, 1984c).

Because of their volatility, the major vector of mono- and dichlorobenzenes to the environment is through the air. Tri- and tetrachlorobenzenes are used primarily as chemical intermediates and as dielectric fluids in electrical equipment. Pentachlorobenzene is minimally used in North America (MOE, 1984c). Hexachlorobenzene is used as a fungicide for cereal and seed crops. Monochlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene and hexachlorobenzene are the most widely dispersed chlorobenzenes in the environment. This is due to their extensive uses and the volatility of the mono and dichlorobenzenes.

With the exception of hexachlorobenzene, chlorobenzenes have relatively low toxicities to humans (WHO, 1984). As with chlorophenols, the toxic effects of chlorobenzenes occur at much higher concentration in water than that required to impair the taste and odour of drinking water. As such USEPA and WHO have set drinking water standards for all chlorobenzenes (except hexachlorobenzene) at levels to prevent the taste and odour impairment of drinking water. These criteria range from 0.1 ug/L (WHO, 1984) for 1,4-dichlorobenzene to 74 ug/L (MOE, 1984c) for pentachlorobenzene.

As discussed above, hexachlorobenzene is used extensively as a fungicide. Although it has a low acute toxicity (WHO, 1984), it is determined by USEPA and WHO to be a potential human carcinogen (MOE, 1984c; WHO, 1984). Therefore both of these agencies have set drinking water criteria for hexachlorobenzene at levels which will allow a risk of 1 additional cancer per 100000 lifetime exposures. The criteria are:

WHO - 0.01 ug/L
USEPA - 0.72 ug/L

Only the MOE has developed surface water quality criteria for chlorobenzenes. These criteria are designed to protect aquatic

organisms. The toxic effects of all chlorobenzenes to aquatic species appear to be quite similar. Chlorobenzenes affect the liver, kidney and possibly gall bladder, and acute doses depress the central nervous system (MOE, 1984c). MOE have drafted guidelines for surface water to minimize these toxicity concerns. They are:

chlorobenzene	- 15 ug/L
dichlorobenzenes	- 2.5 - 4 ug/L
trichlorobenzenes	- 0.5 - 0.9 ug/L
tetrachlorobenzenes	- 0.1 - 0.15 ug/L
pentachlorobenzene	- 0.030 ug/L
hexachlorobenzene	- 0.0065 ug/L.

With the exception of dichlorobenzenes, criteria to protect aquatic species are the more stringent and will also protect humans. As dichlorobenzenes are widely used levels should be maintained below 0.1 ug/L for 1,4-dichlorobenzene and 0.3 ug/L for 1,2-dichlorobenzene to minimize aesthetic concerns in drinking water.

Trichlorotoluenes

In this study, two trichlorotoluenes are being investigated:

2,3,6-trichlorotoluene, and
2,4,5-trichlorotoluene.

These chlorotoluenes were selected for analysis in this study as MOE has identified them as organic chemicals of concern in their St. Clair and Niagara River studies. As well, MOE has identified trichlorotoluenes as priority pollutants under their Municipal-Industrial Strategy for Abatement (MISA) program.

No toxicological information on trichlorotoluenes is available in standard respected reference sources. As well, no water quality standards or criteria have been set for these trichlorotoluenes by MOE, Environment Canada, WHO, IJC, USEPA or HWC.

It can be expected, however, that trichlorotoluenes may exhibit taste and odour concerns in drinking water. This is expected because of the similarity in chemistry between these compounds and trichlorobenzenes and trichlorophenols which are both documented as causing taste and odour problems in drinking water.

Ethers

Ethers are a class of organic compounds in which two organic carbons are attached via an oxygen atom. The eight ethers that have been monitored in the OWMC baseline water quality study are:

bis(2-chloroisopropyl)ether
bis(2-chloroethoxy)methane
4-chlorophenylphenylether
bis(2-chloroethyl)ether
2-chloroethylvinylether
diphenylether
4-bromophenylphenylether
bis (chloromethyl)ether.

With the exception of diphenylether, these compounds are all halogenated ethers and are included on the USEPA's priority toxic pollutants list. They are used as alkylating agents, solvents and soil fumigants. 2-Chloroethylvinylether is used in the manufacture of anesthetics and sedatives.

These ethers tend to be insoluble or just slightly soluble in water. They range in persistence from bis(2-chloroethyl)ether

being moderately persistent to bis(chloromethyl)ether which rapidly decomposes (Sittig, 1981).

The only known human carcinogen in the group is bis(chloromethyl)ether. Even though it is a known carcinogen, the USEPA has proposed removing it from its priority toxic pollutants list. The USEPA states that the possibility of aquatic life and humans being measurably exposed to this chemical through water is extremely remote because of the fact that it is readily decomposed in water. The USEPA (USEPA, 1980, 1985) has published a criterion of 0.0038 ng/L corresponding to a 10^{-6} increase in cancer risk over a lifetime through ingestion of contaminated water and aquatic organisms.

Bis(2-chloroethyl)ether has given positive carcinogenic results in laboratory animals (Sittig, 1981). Based on exposure through ingestion of contaminated water and aquatic organisms. The USEPA has estimated a criterion of 0.03 ug/L for bis(2-chloroethyl)ether corresponding to an increase cancer risk of one in 10^6.

The sources reviewed have provided very little, if any, toxicity information on the other ethers. The USEPA (USEPA, 1980, 1985) ambient water quality criterion for bis(2-isopropyl)ether is 34.7 ug/L for the protection of human health for exposure through contaminated water and aquatic organisms. The agencies surveyed have not established criteria for the other ethers due to insufficient data.

In summary, the criteria found in the sources reviewed in this study are:

bis(chloromethyl)ether - 0.0038 ng/L
bis(chloroethyl)ether - 0.03 ug/L
bis(2-isopropyl)ether - 34.7 ug/L.

Heavy Chloroaliphatics and Chloroolefins

This group is similar to a volatile group of simple organic molecules except they are more heavily chlorinated (see Section 2.9.7.1). Included in this group are hexachloroethane (HCE), hexachlorobutadiene (HCBD) and hexachlorocyclopentadiene (HCCP). These are all included on the USEPA's priority toxic pollutants list. They are used as intermediates in chemical syntheses and as solvents. In addition, HCE is used as a retarding agent in fermentation and as a camphor substitute in nitrocellulose. HCE is also used as a transformer and hydraulic fluid.

Of the three listed above, HCBD and HCE are suspected carcinogens. Laboratory studies have shown them to be toxic to both fish and mammals (Sittig, 1981). The USEPA reports that HCBD can produce toxic effects in fish at concentrations as low as 9.3 ug/L (USEPA, 1980). The carcinogenicity of HCCP has not been demonstrated unequivocally. Fish toxicity data has been used to suggest that a concentration of HCCP of 5.2 ug/L (USEPA, 1980) may pose a 1 in 10^6 risk of cancer. It is based on exposure through ingestion of contaminated water and aquatic organisms.

HCE acts as a central nervous system depressant. It also is a suspected carcinogen (USEPA, 1985). The USEPA suggested a 1 in 10^6 increased cancer risk is encountered by drinking water and consuming aquatic food stuffs drawn from water containing 1.9 ug/L of HCE. Freshwater aquatic life may be at risk from chronic exposures at 540 ug/L.

The USEPA (USEPA, 1980, 1985) has derived two levels of concern for HCCP. The first is 206 ug/L and is based on human health effects. The second, 1.0 ug/L is for control of taste and odour in drinking waters. Although taste and odour concerns are not related to human health effects, the level 1.0 ug/L provides a criterion.

Nitroaromatics

Nitroaromatics are compounds with the $-NO_2$ functional group on the benzene skeleton. Three compounds in this group were studied:

nitrobenzene
2,4-dinitrotoluene
2,6-dinitrotoluene.

All three of these compounds have been listed as priority pollutants by the USEPA who has considered water quality standards for them. All are used as solvents and as intermediates in the manufacture of aniline dyes (NRC, 1986; Sittig, 1981). The dinitrotoluenes are also used to make TNT (trinitrotoluene) explosives (Sittig, 1981).

The toxic effects of nitrobenzene and the dinitrotoluenes are very similar. Acute exposure to these chemicals results in central nervous system depression causing dizziness and headaches (NRC, 1986; Sittig, 1981). Large dose acute exposure to nitrobenzene and dinitrotoluene can cause methemoglobin to form in the bloodstream of humans (NRC, 1986; Sittig, 1981). Methemoglobin prevents the transfer of oxygen in the blood and oxygen starvation results. One of the major symptoms of nitrobenzene and dinitrotoluene poisoning is cyanosis (bluish lips, etc.) directly resulting from methemoglobin formation (NRC, 1986; Sittig, 1981). Many human poisoning cases from exposure to nitrobenzene in shoe dyes and laundry inks have been documented (NRC, 1986).

Drinking water standards for nitrobenzene have been set in two ways by the USEPA. They have determined that the toxic effects of nitrobenzene (methemoglobin production, etc.) from drinking water are minimal at concentrations less than or equal to 19.8 mg/L (in water) (USEPA, 1980, 1985). However, the USEPA has also noted that nitrobenzene produces a distinctive almond odour

in drinking water at concentrations as low as 30 ug/L (NRC, 1986; USEPA, 1980, 1985). Therefore, for this study the criterion for nitrobenzene should be 30 ug/L based on the aesthetic quality of drinking water.

2,4-dinitrotoluene has been identified by the USEPA as a potential human carcinogen (USEPA, 1980, 1985). They have suggested criteria to minimize cancer risks to humans from the ingestion of water and aquatic organisms. A level of 0.11 ug/L presents a one in 10^6 increased lifetime risk to humans from contaminated water used as drinking water and a source of fish (USEPA, 1980).

No suggestions for levels of concern for 2,6-dinitrotoluene were found in the sources reviewed.

Aniline Compounds

Aniline compounds are aromatics with $-NH_2$ functional group on the benzene skeleton. Three compounds are included in this study:

benzidine
3,3-dichlorobenzidine
1,2-diphenylhydrazine.

Benzidine and 3,3-dichlorobenzidine are primarily used in the manufacture of dyes and pigments. 3,3-Dichlorobenzidine is also used as a curing agent for urethane plastics.
1,2-Diplenylhydrazine is used in the manufacture of benzidine and also in the synthesis of phenylbutazone, an anti-inflammatory drug (Sittig, 1981).

Benzidine and 1,2-diphenylhydrazine have been reported to be toxic to aquatic life at concentrations as low as 2.5 mg/L and

0.27 mg/L respectively. There is no data available on the toxicity of 3,3-dichlorobenzidene to aquatic organisms.

Benzidine, 3,3-dichlorobenzidine and 1,2-diphenylhydrazine are of human health concern because of their carcinogenic potential. Benzidine is a known human bladder carcinogen and 3,3-dichlorobenzidine has been shown to be a potent carcinogen in laboratory animals. 1,2-diphenyhydrazine is a suspected carcinogen because of its structural similarity to benzidine. The sources reviewed did not discuss non-carcinogenic bioeffects.

Although considered carcinogenic, neither the WHO nor HWC have set drinking water guidelines for these chemicals. The USEPA (USEPA, 1980) has suggested levels in ambient water to minimize cancer risks in humans. This is based on exposure through ingestion of contaminated water and aquatic organisms. They have estimated concentrations corresponding to a one in 10^6 increased cancer risk over a lifetime, again based on ingestion of both contaminated water and aquatic organisms. These are:

benzidine	0.12 ng/L
3,3-dichlorobenzidine	10.3 ng/L
1,2-diphenylhydrazine	42 ng/L.

Nitrosamines

The nitrosamines are a group of compounds in which a -N-N=O group is attached to an organic carbon. Three nitrosamines have been included in this study:

N-nitroso-n-propylamine
N-nitrosodimethylamine
N-nitrosodiphenylamine

Of particular concern is their use as food additives. They are also used in rocket fuels, as solvents and pesticides.

Nitrosamines are included on the USEPA's priority toxic pollutants list and are of concern because many of them are potent carcinogens, at least in laboratory animals. Non-carcinogenic bio-effects include liver damage. There is little information available on their toxicity and only the USEPA has suggested any levels of concern in the documentation reviewed.

The USEPA (USEPA, 1980, 1986) reports that nitrosamines are toxic to fish at concentrations as low as 5.9 mg/L. They have suggested ambient water concentrations which will minimize the risk of cancer in humans. N-nitrosodimethylamine and N-nitrosodiphenylamine present an incremental lifetime risk of one in 10^6 through exposure by ingestion of contaminated water and aquatic organisms as follows:

N-nitrosodimethylamine	1.4 ng/L
N-nitrosodiphenylamine	4900 ng/L.

MISCELLANEOUS COMPOUNDS

Isophorone

Isophorone, a trimethylcyclohexenone, is an industrial chemical synthesized from acetone. It is used as a solvent in a variety of applications and also as a feedstock in the production of a number of chemicals. It is slightly water soluble and as a result of its industrial use, it can enter surface waters via plant effluents.

The sources reviewed reported very little toxicological information on isophorone. The USEPA (USEPA, 1980, 1986) reports that it has been found to be toxic to aquatic life at concentrations as low as 117 mg/L. Human health effects of exposure

include throat irritation, headaches and dizziness (Sittig, 1981). The USEPA's (USEPA, 1980, 1981) ambient water criterion for the protection of human health is 5.2 mg/L. This is based on exposure through ingestion of contaminated water and aquatic organisms.

Biphenyl and Naphthalene

Biphenyl is used as a fungistat for citrus fruit which is applied inside shipping containers and wrappers and as a heat transfer medium. Naphthalene is used extensively as a moth repellant. Both are used industrially as intermediates in the synthesis of other organic chemicals.

The toxicity of biphenyl is very low. The USEPA has not included it on their list of priority pollutants. Biphenyl exposure can impact the central nervous system, the peripheral nervous system and liver. Symptoms include headache, nausea, indigestion, numbness and general fatigue. The USEPA (Sittig, 1981) has suggested an ambient water criterion of 13.8 ug/L based on health effects. The MOE analyzed for biphenyl in both the St. Clair and Niagara River studies.

Naphthalene is included on the USEPA's priority toxic pollutants list. The major concern with naphthalene is that it can cause hemolyptic anemia in people deficient in glucose-phosphate dehydrogenase. The incidence of this deficiency has been estimated (Sittig, 1981) as 0.1% in American caucasians, as high as 20% in American blacks and up to 50% in certain Jewish groups. Even without the GGPD deficiency, newborn babies are susceptible to the hemolytic effects of naphthalene exposure. Freshwater aquatic chronic toxicity criterion is 620 mg/L (USEPA, 1985).

2-Chloronaphthalene

2-Chloronaphthalene is a naphthalene in which one hydrogen atom have been substituted with a chlorine atom. Chloronaphthalenes,

in general, tend to be very stable and are used extensively in industry in electric cable and wire insulation, as additives to extreme pressure lubricants, as supports for storage batteries and in the production of electric condensers.

Chlorinated naphthalenes are included on the USEPA's priority toxic pollutants list. Their toxicity increases as chlorine substitution increases (Sittig, 1981). The USEPA (USEPA, 1980) reports that chlorinated naphthalenes are toxic to certain species of fish at concentrations as low as 1.6 mg/L.

Because of the lack of toxicity data, guidelines have not been set for the protection of human health.

PRIORITY ORGANICS: VOLATILES

Chloroaliphatics and Chloroolefins

Chloroaliphatics are chlorinated straight-chain or branched hydrocarbons. They include the following chemical species which are of concern because of their wide industrial use:

Chloromethanes -	chloromethane
	methylene chloride
	carbon tetrachloride
Chloroethanes -	chloroethane
	1,1-dichloroethane
	1,2-dichloroethane
	1,1,1-trichloroethane
	1,1,2-trichloroethane
	1,1,2,2-tetrachloroethane

Chloroethylenes - vinyl chloride
1,1-dichloroethylene
trans-1,2-dichloroethylene
trichloroethylene
tetrachloroethylene

Chloropropanes - 1,2-dichloropropane
1,3-dichloropropene.

The chloromethanes are used as solvents, in the synthesis of other organic chemicals, and some as aerosol propellants and pesticides. They are insoluble or just slightly soluble in water. The persistence of the chloromethanes in the aquatic environment ranges from chloromethane being easily hydrolyzed to carbon tetrachloride which is highly persistent. They are readily absorbed from the gastrointestinal tract and affect the central nervous system, liver, and kidneys. Methylene chloride is also known to affect the oxygen carrying capacity of the blood (Lappenbusch, 1986). Carbon tetrachloride is a proven carcinogen in mice (WHO, 1984) and there is supporting evidence that it may be carcinogenic in other species as well.

Based on the carcinogenic potential of carbon tetrachloride and its frequent occurrence in surface waters, the WHO (WHO, 1984) has set a tentative water quality guideline of 3 ug/L. The USEPA (USEPA, 1980) has established that for the protection of human health from the potential carcinogenic effects of carbon tetrachloride through ingestion of contaminated water and aquatic organisms the ambient water concentration should be minimized. They have estimated incremental cancer risk of one in 10^6 when a lifetime exposure to water at 0.4 ug/L occurs. They have recently proposed a drinking water Maximum Contaminant Level (MCL) of 5 ug/L for carbon tetrachloride. No other sources reviewed provide guidance on the chloromethanes.

Chloroethanes are used extensively as intermediates in organochlorine production and as solvents. They are produced and used in large quantities in North America. Bromoethane can be considered as a member of this group because of its structural and toxicological similarity to chloroethane. The chloroethanes are just slightly soluble in water but have been detected in raw and treated waters (WHO, 1984).

The aquatic toxicity of the chloroethanes increases quickly with increasing chlorination (USEPA, 1980). They tend to attack the central nervous system, liver and kidneys. They act as narcotics causing nervous system depression.

1,2-Dichloroethane is a proven carcinogen and the WHO (WHO, 1984) has recommended a drinking water guideline of 10 ug/L by applying a multi-stage linear extrapolation model to data obtained from studies on rats. The USEPA's recently proposed drinking water MCL for 1,2-dichloroethane is 5 ug/L (Vogt, 1987). The USEPA's criterion for 1 in 10^6 increased cancer risk for 1,2-dichloroethane is 0.94 mg/L when exposure is through drinking water and consumption of aquatic organisms (USEPA, 1985).

Both the 1,1,1- and 1,1,2- isomers of trichloroethane are suspected carcinogens. The USEPA (USEPA, 1980) has set a MCL of 200 ug/L for trichloroethane in drinking water. They recommend an ambient water concentration of 18.4 ug/L for protection of human health from the toxic properties of 1,1,1-trichloroethane ingested through contaminated water and aquatic organisms (USEPA, 1985). For the protection of human health from the potential carcinogenic effects of 1,1,2-trichloroethane through ingestion of contaminated water and aquatic organisms, they recommend minimal exposure to water containing this chemical. They suggest a one in 10^6 increased risk of cancer from a lifetime exposure to water at 0.6 ug/L of 1,1,2-trichloroethane.

1,1,2,2-tetrachloroethane is a potential carcinogen and the USEPA (USEPA, 1980) recommends minimal exposure, as above. A one in 10^6 increased risk is associated with using water at 0.17 ug/L as a source of drinking water and dietary fish.

Freshwater aquatic chronic toxicity for these compounds is summarized as follows:

1,2-dichloroethane	20 mg/L
1,1,2-trichlorethane	9.4 mg/L
1,1,2,2-tetrachloroethane	2.4 mg/L.

The chloroethylenes are used in industry as solvents, film softeners, paint and varnish thinners, dry-cleaning fluids, etc. They are insoluble or just slightly soluble in water and have been found in raw and treated waters. They are volatile and are lost from surface water. Therefore their concentration depends on exposure time and temperature.

All of the chloroethylenes examined in this study are known or suspected carcinogens. Non- carcinogenic effects include central nervous system depression causing headaches, dizziness, blurred vision, etc.

Vinyl chloride is a well known human carcinogen. The WHO (WHO, 1984) has not established a guideline value for it because they consider that its occurrence in drinking waters is due to poorly polymerized PVC pipes which is a product quality control problem. The USEPA has recently proposed a MCL of 1 ug/L for drinking water (Vogt, 1987). They suggest a 1 in 10^6 risk of cancer is incurred by using raw water at 2 ug/L as a source for drinking water and aquatic food.

Of the dichloroethylenes, the isomer that is of the most concern is 1,1-dichloroethylene which shows evidence of carcinogenicity in laboratory animals however, it is doubtful that

either of the 1,2-isomers is carcinogenic at drinking water levels (Lappenbusch, 1986). The WHO (WHO, 1984) has applied a linear multi-stage model to data obtained on mice to establish a drinking water guideline value of 0.3 ug/L for the 1,1-isomer. The USEPA has proposed a MCL of 70 ug/L for drinking water for the 1,2-isomer and 7 ug/L for the 1,1-isomer (Vogt, 1987).

The WHO (WHO, 1984) reports that both trichloroethylene and tetrachloroethylene (also known as perchloroethylene) have been found to produce tumors in mice. Their carcinogenic potential has not been confirmed but the WHO has set tentative drinking water guidelines of 30 ug/L and 10 ug/L for trichloroethylene and tetrachloroethylene respectively. The USEPA's recently proposed drinking water MCL is 5 ug/L for trichloroethylene.

The USEPA has summarized human and freshwater effects (USEPA, 1985). The human health effects are expressed in 1 in 10^6 increased cancer risk levels for water used as a raw water source and source of aquatic food.

	Human Health ug/L	Freshwater Aquatic ug/L
1,1-dichloroethylene	.033	11600
t-1,2-dichloroethylene	-	11600
trichloroethylene	2.7	45000
tetrachloroethylene	0.8	840

Chloropropanes and chloropropenes are usually found in mixtures used a soil fumigants and fungicides. 1,3-dichloropropene has been found to be carcinogenic in laboratory animals (NRC. 1986) and is considered to have low tumor causing potential (Sittig, 1981). The USEPA recently proposed a recommended maximum contaminant level (RMCL) of 6 ug/L for 1,2-dichloropropane (Vogt, 1987). Their ambient water quality criterion is 87 ug/L for the protection of human health from the

toxic properties of dichloropropanes ingested through contaminated water and aquatic organisms. Freshwater species are protected by criteria of 5700 ug/L and 244 ug/L for 1,2-dichloropropane and 1,3-dichloropropenes respectively.

Trihalomethanes

Trihalomethanes (THMs) are halogenated single carbon compounds having the general formula CHX_3 where X is chlorine, bromine, iodine, fluorine, or combinations of these. The THMs are not very water soluble and they are slowly biodegradable.

Four trihalomethanes have been detected in numerous water supplies and as a result have been extensively studied. These are chloroform ($CHCl_3$) bromodichloromethane, ($CHBrCl_2$) dibromochloromethane ($CHBr_2Cl$) and bromoform ($CHBr_3$). The concentrations of these four THMs in drinking water are often higher than any other synthetic organics. They are formed when water is contacted with chlorine for disinfection. Chloroform is the one most often detected.

The chief uses of chloroform are in the synthesis of chlorodifluoromethane which is a refrigerant and polytetrafluoroethylene (Teflon®). It is also an important solvent and degreasing agent. Bromoform is also used as in intermediate in organic syntheses and as a solvent for waxes, greases and oils. Dibromochloromethane is used as an intermediate in the manufacture of fire extinguishing agents, aerosol propellants, refrigerants, and pesticides. Only chloroform is manufactured in Canada. These THMs can enter natural waters as a result of waste disposal and wastewater treatment but are often not detected. It is expected they would be lost quickly to the atmosphere.

The major source of THMs in drinking water is chemical interaction of chlorine, added for disinfection, with naturally

occurring organic substances in the raw water. Human exposure to THMs is primarily through drinking water consumption since the THMs are widely occurring in drinking water.

Because chloroform is the THM most often detected in drinking water and in the highest concentrations it is the one most often studied. Chloroform and bromoform have been shown to be carcinogenic in laboratory animals (NRC, 1977; NRC, 1980b) and are considered to be potential human carcinogens. It is assumed that the other THMs have similar toxicities.

The WHO (WHO, 1984) has set a water quality guideline of 30 ug/L for chloroform. This was obtained using a linear multi-stage extrapolation of data obtained from male rats. They recommend that the control of chloroform concentrations will effectively control of the other THMs.

The USEPA (USEPA, 1980) reports that the ambient water concentration should be minimized for the protection of human health from the potential carcinogenic effects due to exposure of chloroform through ingestion of contaminated water and aquatic organisms. They also suggest the one in 10^6 incremental cancer risk as being 0.19 ug/L. This is based on the ingestion of contaminated water and aquatic organisms.

HWC MAC (HWC, 1980) for trihalomethanes in drinking water is 0.35 mg/L. Using a linear one-hit model they determined the maximum cancer risk for a 70 kg adult ingesting 2 L of water a day containing 0.35 mg/L chloroform to be 1 in 2.5 million per year. They consider this to be an acceptable cancer risk. The MOE's drinking water criterion (MOE, 1983) is also 0.35 mg/L.

Benzenes

Benzene and its aliphatic derivatives (toluene, ethylebenzene, and xylene) are volatile organic contaminants that have been detected in some surface waters. They are constituents of crude oil and coal and are used in a number of applications including the manufacture of styrene and synthetic rubber, as components of certain fuels, as constituents in paints and varnishes, and as solvents. As a result of their wide use they can enter surface water via industrial effluents.

These benzenes tend to be insoluble or just slighlty soluble in water. Because of their volatility they are more of an air contaminant than a water contaminant. Spills may lead to direct input into groundwater where they will be found at higher concentrations than in surface water because they will volatilize to atmosphere in open systems. However, because of their lipophilicity they do possess bioaccumulative potential. The MOE (MOE, 1984a) reports that they are accumulative in fish at concentrations greater than 1 000 times the ambient water concentrations. Their toxicity to fish ranges from moderately toxic to very toxic. The MOE has not defined tolerance limits for the benzenes.

Benzene is the only known human carcinogenic in this group and there is strong evidence (NRC, 1977) that benzene exposure can cause leukemia in susceptible individuals. Because of the carcinogenic potential of benzene and the fact that it has been found in raw water supplies, the WHO (WHO, 1984) has recommended a water quality guideline of 10 ug/L. This guideline is based on a linear multistage model applied to leukemia data. The USEPA has recently proposed a MCL of 5 ug/L for benzene (Vogt, 1987).

The USEPA has suggested a one in 10^6 increased cancer risk for benzene at a lifetime consumption level of 0.66 ug/L for water

used for drinking source and source of aquatic food organisms (USEPA, 1980).

Toluene acts as a narcotic causing central nervous system depression. It is readily metabolized to benzoic acid and hippuric acid which are relatively innocous. In fact, benzoic acid is an approved food additive. The USEPA's (USEPA, 1980) 1980 ambient water quality criterion is 14 300 ug/L for the protection of human health from toluene toxicity ingested through contaminated water and aquatic organisms. They have recently proposed a recommended maximum contaminant level of 2 000 ug/L. Freshwater chronic aquatic toxicity criterion is 17 500 ug/L (USEPA, 1985).

Ethylbenzene is moderately toxic to humans. It is absorbed through the gastrointestinal tract and impacts the liver, kidneys and central nervous system (Lappenbusch, 1986). The USEPA (USEPA, 1980) recommends an ambient water criterion of 1 400 ug/L for protection from exposure through ingestion of contaminated water and aquatic organisms and have recently proposed a RMCL of 680 ug/L. Freshwater chronic aquatic toxicity criterion is 32 000 ug/L (USEPA, 1985).

Commercial xylene (dimethylbenzene) is a mixture of isomers, ortho, para, and meta. Mixtures are primarily composed of the meta isomer. Although the xylenes can bioaccumulate and are very toxic to fish (MOE, 1984a), in humans they are rapidly oxidized to more polar metabolites which are water soluble and readily excreted. Xylenes have not been regulated in drinking water but the USEPA has recently proposed a recommended maximum contaminant level of 440 ug/L.

Miscellaneous Volatiles: Acrolein, Acrylonitrile

Acrolein, or acrylaldehyde, is used as an intermediate in glycerine production, as a slimicide in paper production, to control algae and aquatic plants, and as a liquid fuel. It is water soluble but because of its high volatility, does not persist in water. Therefore, human exposure is primarily via inhalation.

Acrolein is toxic by ingestion (Sittig, 1981). The USEPA (USEPA, 1980) reports that acrolein is toxic to aquatic life at concentrations as low as 21 ug/L. Their ambient water quality criterion for protection of human health from acrolein toxicity through ingestion of contaminated water and aquatic organisms is 320 ug/L (USEPA, 1980, 1985).

Acrylonitrile, a monotrile having the formula CH_2CHCN, is used as a fumigant to protect grain and tobacco from insects and is used in the manufacture of synthetic fibres. It is miscible with water in all proportions but because of its volatility, air contamination is a greater concern than water contamination.

There is very little information on the persistence of acrylonitrile in the water environment. The MOE (MOE, 1984a) reports that it is moderately toxic and may produce tainting in fish. They have listed it as a substance with an undefined tolerance limit since it is of concern but there is insufficient data available to establish a water quality objective.

Human exposure to acrylonitrile is primarily via inhalation. It is carcinogenic (Lappenbusch, 1986) and the USEPA (USEPA, 1980) suggests that for the protection of human health from the potential carcinogenic effects of acrylonitrile through ingestion of contaminated water and aquatic organisms, the ambient water concentration should be minimized. They suggest a one in 10^6

incremental cancer risk over a lifetime is incurred at a 0.58 ug/L exposure in drinking water, food and fish. HWC and the WHO have not published guidelines for acrylonitrile.

REFRACTORY ORGANICS

Polynuclear Aromatic Hydrocarbons (PAHs)

Polynuclear aromatic hydrocarbons (PAHs) are a group of organic compounds each of which is composed of two or more fused benzene rings (i.e. adjacent rings sharing two carbon atoms). Non-aromatic side chains or rings may also be present. The group includes a large number of chemicals of which the following are found most frequently in environmental samples:

acenaphthene
anthracene
benzo(a)anthracene
benzo(b)fluoranthene
benzo(a)pyrene
benzo(j)fluoranthene
benzo(k)fluoranthene
benzo(ghi)perylene
chrysene
dibenzo(ah)anthracene
fluorene
fluoranthene
indeno(1,2,3-cd)pyrene
pyrene
phenanthrene
perylene

The most studied member of the group is benzo(a)pyrene.

PAHs occur widely in the environment as complex mixtures. They are synthesized in small amounts by micro-organisms, phytoplankton, algae, and plants (Lappenbusch, 1986). They are also produced by incomplete combustion of organic compounds in the

presence of insufficient oxygen resulting in the formation of C-H radicals which polymerize to form PAHs (Lappenbusch, 1986). The major sources of PAHs in the environment are thermal power stations, waste incinerators, internal combustion engines, and high temperature industrial processes, including petroleum cracking, and the production of coke, carbon black, coal tar pitch, and asphalt road mix (Lappenbusch, 1986). They enter natural waters via discharges of raw and industrial wastewater, atmospheric fallout and precipitation, road runoff, and leachate from polluted soils (Lappenbusch, 1986).

PAHs tend to be insoluble or just sparingly soluble in water, due to their high molecular weight and lack of polar substituent groups (Lappenbusch, 1986). Their solubility can be greatly increased by the presence of detergents and other surfactants (Lappenbusch, 1986). They would be expected to be highly absorbed on suspended matter in water. They are quite stable in water and remain there for substantial periods of time (USEPA, 1980). Even though the environmental fate of this group as a whole has not been clearly defined, it is known that they are observed on suspended particulate matter and undergo sedimentation and micorbial degradation (USEPA, 1980). Conventional water treatment methods are effective in removal of PAH contamination (Lappenbusch, 1986). However, they can leach from tar or asphalt lined pipes used in some distribution systems (Lappenbusch, 1986).

Humans are exposed to PAHs via food, drinking water and air. It has been estimated that drinking water accounts for 0.1% for the total exposure while food consumption accounts for 99% (Lappenbusch, 1986). Since PAHs are highly lipid soluble they are readily absorbed from drinking water through the gastrointestinal track (USEPA, 1986) and tend to concentrate in body fat and fatty tissues (Lappenbusch, 1986). PAH accumulation in fish is 100-1000 times that in water in which the fish are found.

Certain PAHs, including benzo(a)pyrene, anthracene, and benzo(a)anthracene are known to be carcinogenic in laboratory animals. They are suspected carcinogens in humans (WHO, 1984) but there has been no absolute proof that PAHs in drinking water cause human cancer (USEPA, 1980). However, the major concern with PAHs is their carcinogenic potential and even though only a small proportion of the total intake of PAHs is via drinking water, health agencies have attempted to minimize this exposure as much as possible.

The USEPA (Sittig, 1981) suggests that for protection of human health from the potential carcinogenic effects of PAHs due to exposures through ingestion of contaminated water and aquatic organisms, the ambient water concentration should be minimized. The incremental risk of cancer is one in 10^6 for a lifetime exposure to PAH as a concentration of 2.8 ng/L through ingestion of contaminated water and aquatic organisms. This estimate assumes that each PAH is comparable to benzo(a)pyrene and since exposure is most likely to be that of a complex mixture, that the chemical interaction is additive (USEPA, 1980). The USEPA (Sittig, 1981) has also estimated a level of 20 ug/L for acenaphthene to control undesirable taste and odour of water. For the protection of human health from the toxic properties of fluoranthene through ingestion of contaminated water and aquatic organisms, the USEPA (Sittig, 1981) ambient water criterion is 42 ug/L. Benzo(a)pyrene stands out as the most toxic member of this group and is often used as the conservative surrogate for the whole class of chemicals.

The WHO (WHO, 1984) has not set a guideline value for the group as a whole due to lack of substantiated toxicological data. However, based on the application of the linear multi-stage extrapolation model to available toxicological data for benzo(a)pyrene and taking into account the fact that it is associated with other carcinogenic PAHs, the WHO (WHO, 1984) has

proposed a drinking water quality guideline of 0.01 ug/L for benzo(a)pyrene. They note that the model cannot be experimentally verified and that uncertainties of two orders of magnitude could exist. The WHO's 1970 European standard for drinking water proposed a limit of 0.2 ug/L for the sum of six indicator PAHs, including fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, benzo(b)fluoranthene, benz(k)fluoranthene and indeno(1,2,3-cd)-pyrene (WHO, 1984). This level was based on the premise that the quality of all drinking water should be comparable with that of ground water found at the time. Unfortunately, this concept is not always applicable and does not consider toxicological effects.

HWC has not established a MAC because of the lack of available data on human health implications or the presence of PAHs in drinking water and on the levels that occur in Canadian water supplies.

Similarly, the Ontario MOE (MOE, 1984a) has not established a water quality objective due to lack of scientific data. They have, however, listed PAHs as substances of primary concern for the protection of the environment.

In summary, the following criteria were found for PAHs in the sources reviewed:

acenaphthene	-	20 ug/L
fluoranthene	-	42 ug/L
benzo(a)pyrene	-	0.01 ug/L.

Polychlorinated Biphenyls (PCBs)

PCB is the acronym given to a family of compounds based on the chlorination of the biphenyl molecule. PCBs are highly lipophilic and are known to bioaccumulate in aquatic systems. The toxicity of PCBs is not clear-cut although one landmark study

(Kimbrough et. al., 1975) suggests a carcinogenicity with the liver as the target organ. Many studies have been confounded by the complexity of the PCB mixture and the presence of trace contaminants of greater toxicity. Some of the PCB congenitors are very chemically similar to dioxins in chemical configuration and a similar mode of action is anticipated. The persistence of this group of chemicals and the bioaccumulation gives scientists cause to consider the potential for a lengthy latency period: the effects are poorly understood but could quite possibly be very severe. They have long latencies such that is has been prudent to ban them from further industrial use. This concern has led to unusually low criterion for a parameter for which the direct evidence is so inconclusive. There is an element of popularity among regulators to use PCBs as the indicator of hazardous chemical contamination. The levels established for PCBs reflect this; in drinking water the interim guideline is 3 ug/L, in ambient water the requirement is 1 ng/L, which is essentially non-detectable in all but the most rigorous and complex analytical protocols (MOE, 1983).

The USEPA has estimated that a criterion of 0.014 ug/L is required to protect freshwater aquatic life. This is based on a standard extrapolation. Actual data suggests that a level of 2 mg/L will be sufficient to protect freshwater organisms.

For human health protection the one in 10^6 increased cancer risk concentration is 0.079 ng/L for ambient water used as a source of raw water for drinking and as a source for aquatic food stuffs.

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs and PCDFs)

Both the Ontario MOE (MOE, 1985) and the National Research Council (National Research Council Canada, 1981, 1984) have published

comprehensive criteria documents on PCDDs and PCDFs. What follows is a brief summary of these publications. PCDDs and PCDFs are structurally and toxicologically similar and will be discussed together.

Polychlorinated-p-dioxins (PCDDs) is a group of 75 organochlorine compounds. Each PCDD is a triple ring structure made up of two benzene rings connected to each other by two ether linkages. The individual PCDDs differ by the number and position of chlorine atoms attached to the benzene rings. "Dioxin" is often used to refer to the specific compound 2,3,7,8-tetrachlorodibenzo-p-dioxin. This is the most toxic of all the PCDDs and is the one most studied.

The term polychlorinated dibenzofurans (PCDFs) refers to a group of 135 related chlorinated hydrocarbons. Each member of the group is a triple ring structure consisting of two benzene rings joined by a single ether linkage and a carbon-carbon bond. The PCDFs differ in the number and position of chlorine atoms attached to the benzene rings.

Neither PCDDs nor PCDFs are intentionally manufactured for any purpose. They are by-products of other processes. PCDD and PCDF contamination has been associated with the manufacture of chlorophenols and the formulation of 2,4,5-T and, 2,4-D herbicides. Since the manufacture of these chemicals is not carried out in Ontario, the main sources of PCDDs and PCDFs in the Ontario environment are incineration processes, use of products which contain traces of PCDDs and PCDFs and migration from industrial (manufacturing) sources in bordering U.S. states. PCDDs and PCDFs from these sources are complex mixtures with only a small proportion of 2,3,7,8-TCDD.

PCDDs and PCDFs are lipophilic and are very stable, with stability increasing with the number of chlorine atoms present.

Being stable and lipophilic they are widespread and persistant in the environment and can potentially bioaccumulate.

The toxicity of PCDDs and PCDFs is dependent on the number and position of chlorine atoms. The most toxic members of the groups are those containing four to six chlorine atoms in the lateral positions. The 2,3,7,8-congenor in both cases is the most toxic of the PCDDs and PCDFs. The actual mechanisms of toxicity of these compounds has not been clearly defined. However, carcinogenicity is assumed to be the most sensitive toxic endpoint (MOE, 1985).

The MOE (MOE, 1985) reports that PCDDs or PCDFs have not been found in Ontario drinking water. Next to ambient air the major route of human exposure is ingestion of contaminated fish.

Based on TCDD toxicity data in rats, the U.S. National Academy of Sciences (NRC, 1977) has calculated an acceptable daily intake (ADI) of 10^{-7} mg/kg/day for TCDD. Assuming 1% of the total ADI is assigned to water their Suggested No Adverse Response Level (SNARL) from water is 0.0007 ug/L. The MOE (MOE, 1985) has used data from chronic animal studies and human epidemiological data to develop a recommended ADI of 10^{-6} mg/kg/day but have not developed a water quality criteria.

The WHO has no guideline and HWC has not published a maximum acceptable concentration.

Clearly, because of the bioaccumulation of PCDDs and PCDFs and their carcinogenic potential their presence in surface water should be eliminated. They should be evaluated against the lowest attainable detection limits.

PESTICIDES

Aldrin/Dieldrin

Aldrin and dieldrin are cyclodiene insecticides. They are derivatives of hexachlorocyclopentadiene produced by the Diels-Alder reaction. Dieldrin is the epoxide of aldrin. Both aldrin and dieldrin are used in the control of worms, termites, ants, and boll weevils (Lappenbusch, 1986).

As with other cyclodienes, little is known of their degradation and fate in the environment. However, trace amounts are ubiquitous in the enviornment and because of their presistence, they are found in surface waters virtually everywhere. They are lipophilic and as such they accumulate in body fat, and progress through the food chain. They are both carcinogenic, the critical organ is the liver.

The USEPA (USEPA, 1980, 1985) criteria, to protect freshwater aquatic life are 3 mg/L and 1.9 mg/L for aldrin and dieldrin respectively. The criterion was developed to ensure that, on average, a reasonable amount of protection to aquatic organisms is provided.

The USEPA has not published drinking water MCLs for aldrin and dieldrin. Previously their approach to the protection of human health from the potential carcinogenic effects of exposure to these chemicals was to set the drinking water concentration at zero. They have listed levels which may result in incremental increase in cancer risk over a lifetime (USEPA, 1980). These levels, based on ingestion of contaminated water and aquatic organisms suggest a one in 10^6 incremental cancer risk is incurred by exposure to water at 0.074 and 0.071 ng/L for aldrin and dieldrin respectively.

For chlorinated pesticides a significant portion of the vector for these materials to humans is through consumption of aquatic organisms. The WHO has published an ADI of 0.0001 mg/kg/day for aldrin and dieldrin (WHO, 1984). This ADI is again based on the possible carcinogenic effects of these pesticides. Using this ADI the MOE (MOE, 1983) and HWC (HWC, 1980) have derived MACs of 0.7 ug/L for aldrin plus dieldrin. Because of the human carcinogenic potential of these pesticides the concentrations of aldrin + dieldrin in drinking water are of greatest concern.

Chlordane

Chlordane is a cyclodiene insectide used extensively over the past 30 years for termite control, as an insectide for homes and gardens, and as a control for soil insects (WHO, 1984). It exists as two isomers (alpha-chlordane and gamma-chlordane) and both form a single epoxide, oxychlordane.

As with other cyclodienes, chlordane is persistant in the environment, accumulating in body fat. It has caused both carcinogenic and non-carcinogenic effects (Lappenbusch, 1986). The liver is the important organ for cancer induction.

Water quality objectives, guidelines and criteria are given for total isomers of chlordane. The ADI published by the WHO for chlordane is 0.001 mg/kg body weight (WHO, 1984). Based on the assumption that not more than 1% of the ADI is derived from drinking water, the WHO drinking water guideline value is 0.3 ug/L. Using the WHO ADI, HWC and the MOE have calculated MACs of 7.0 ug/L for drinking water (MOE, 1983; HWC, 1980).

For the protection of aquatic life the USEPA criterion is 2.4 ug/L (USEPA, 1980). For the protection of human health from the potential carcinogenic effects due to exposure of chlordane, the USEPA recommended an ambient water concentration of zero.

They have suggested a level which may result in incremental increase in cancer risk of 10^{-6}. This level is 0.46 ng/L. This level is for exposure through ingestion of contaminated aquatic organisms as well as contaminated water (USEPA, 1986).

The MOE (MOE, 1984a) has set a Provincial Water Quality Objective of 0.06 ug/L to ensure protection of aquatic life. This level is lower than the drinking water criterion. The USEPA (USEPA, 1985) has suggested a criterion of 0.0043 mg/L for the protection of freshwater aquatic life.

Parathion and Methylparathion

Parathion and methyl parathion are highly toxic organophosphorus insectides used to protect forage, field and vegetable crops. They are both slightly soluble and are hydrolyzed in water. The sources reviewed provided very little information on the persistence and fate of these pesticides in the environment. Methylparathion is hydrolyzed much faster than parathion and is less persistent in natural water. Based on their physical, chemical and biological properties, they are not expected to bioaccumulate.

Parathion and methylparathion are oxidized in the environment and in the body to the corresponding oxygen analogues, which are the toxic forms of these materials. Their oxidized forms are toxic via inhibition of the enzyme acetylcholinesterase. Symptoms of exposure include nausea, vomiting, diarrhea, blurred vision and difficult breathing.

An ADI of 0.001 mg/kg for methylparathion and 0.0005 mg/kg parathion were established by the WHO in the late 1960's (NRC, 1977). HWC (HWC, 1980) and the MOE (MOE, 1984) have used these ADIs to calculate MACs of 7 ug/L for methyl parathion and 35 ug/L for parathion. WHO has no guideline and the USEPA has no standard. No criteria are published for the protection of the aquatic environment.

Diazinon

Diazinon, or O,O-diethyl O-(2-isopropyl-4-methyl-6-pyrimidinyl)-phosphorothioate, is an organophosphorus insectide used extensively on crops and animals (Lappenbusch, 1986; NRC, 1977). It is actively used in Ontario (MOE, 1984a) on a wide variety of domestic animals, lawns and gardens, and household plots. Because of its use around the home it may contaminate drinking water.

Diazinon is not carcinogenic (Lappenbusch, 1986). It's mode of action, as with other organophosphorus insecticides, is inhibition of the enzyme cholinesterase and therefore it impacts the nervous system (NRC, 1977).

The National Academy of Sciences (NRC, 1977) reports that diazinon is relatively non-persistant in soil being lost through chemical and biological degradation processes. Little is known about its behaviour in the aquatic environment.

The Great Lakes Water Quality Agreement criterion for the protection of the aquatic habitat is 0.08 ug/L (IJC, 1985). This is also the objective of the Ontario MOE (MOE, 1984a), again for the protection of the aquatic environment.

The WHO has provided no guideline for diazinon and there is no USEPA standard. The WHO did publish an ADI of 0.002 mg/kg body weight in 1975. The MOE and HWC have used this ADI to calculate MACs of 14.0 ug/L (HWC, 1980; MOE, 1983).

Benzene Hexachloride

Benzene hexachloride (BHC) is the common name for a mixture of isomers of 1,2,3,4,5,6-hexachlorocyclohexane used for insecticidal purposes. Technical grade BHC is a mixture of the eight possible isomers, primarily the alpha isomer with lesser amounts of beta, gamma, etc. The product containing 99% gamma isomer is the commercial insectide Lindane.

The alpha, beta, and gamma isomers are carcinogenic and the critical organ in the liver (Lappenbusch, 1986). Lindane is the most toxic of the BHC isomers (NRC, 1977; Sittig, 1981) and therefore criteria are given for lindane.

The ADI published by the WHO for lindane is 0.01 mg/kg of body weight and from this they have derived a drinking water guideline value of 3 ug/L (WHO, 1984). The ADI is based on an "acceptable cancer risk" of 1 in 100000 over a lifetime exposure. HWC and the MOE have used this ADI to calculate MACs of 4 ug/L for drinking water (HWC, 1980; MOE, 1983).

The criterion developed by the USEPA for lindane to protect freshwater aquatic life is 0.08 ug/L as a 24-hour average and 2.0 ug/L at any time (USEPA, 1980). They have also published criteria estimates which may result in an incremental increase of cancer risk over a lifetime. For a one in 10^6 incremental risk the suggested level is 18.6 ng/L.

The Ontario MOE objective for ambient water quality for lindane is 0.01 ug/L (MOE, 1984a). This value of 0.01 ug/L is also published by Environment Canada as the water quality guideline for lindane for the protection of freshwater aquatic life (Environment Canada, 1979) and also be the IJC in the Great Lakes Water Quality Agreement (IJC, 1985).

The criterion for the protection of the aquatic habitat is significantly lower than criteria set for human health effects. The USEPA has suggested (USEPA, 1985) a level of 0.08 ug/L as one that is necessary to protect freshwater aquatic organisms.

Heptachlor and Heptachlor Epoxide

Heptachlor and heptachlor epoxide are cyclodiene insecticides derived from hexachlorocyclopentadiene.

They are used in the US principally as pre-emergence soil insecticides for the control of corn rootworms, wireworms, cutworms, termites and ants (NRC, 1977). They are not actively used in Ontario (MOE, 1984a).

As with other cyclodiene insecticides, heptachlor, and especially heptachlor epoxide, are very stable. They accumulate in body fat, pass through the food chain and thus undergo biologic magnification (NRC, 1977). They cause both carcinogenic and non-carcinogenic effects (Lappenbusch, 1986). The non-carcinogenic bioeffects include headache, blurred vision, dizziness, muscle impairment, sweating, nausea, and unpleasant dreaming. The organ of concern for cancer is the liver. The concentration associated with a one in 10^6 increase in cancer risk is 0.28 ng/L (USEPA, 1980).

The Ontario MOE, HWC, and the WHO have set criteria for heptachlor and heptachlor epoxide based on health concerns. The WHO (WHO, 1984) has published an ADI of 0.0005 mg/kg body weight and a water guideline of 0.1 ug/L. HWC (HWC, 1980) and the MOE (MOE, 1983) have used the WHO's ADI to calculate MACs of 3 ug/L. The USEPA at present does not have drinking water standards for heptachlor and heptachlor epoxide.

For the protection of aquatic life the USEPA criterion is 0.0038 ug/L (USEPA, 1980, 1985). The MOE has set a water quality objective of 0.001 ug/L (MOE, 1984a) again based on protection of the aquatic environment.

Environment Canada's water quality guidelines for heptachlor and heptachlor epoxide in raw water supply are both 18.0 ug/L (Environment Canada, 1979). This criterion is based on human health concerns. The IJC's criterion under the 1978 Great Lakes Water Quality Agreement is 0.001 ug/L (IJC, 1985).

Endrin

Endrin is a cyclodiene insecticide used to control worms, termites, ants, and boll weevils (Lappenbusch, 1986). It is not actively used in Ontario (MOE, 1984a).

Endrin is the steroisomer of dieldrin but unlike dieldrin, the extent of storage of endrin in animals is small (Agriculture Canada, 1982). However, it does persist in the environment and does accumulate in body fat causing both carcinogenic and non-carcinogenic biological effects (Lappenbusch, 1986). Its toxicity results from its effect on the central nervous system and the most common cause of death from endrin poisoning is respiratory failure (Sittig, 1981). The organ of concern for cancer is the liver (Lappenbusch, 1986).

For endrin, the USEPA criterion to protect freshwater aquatic life is 0.0023 ug/L (USEPA, 1980). The MOE's objective for the protection of the aquatic habitat is 0.002 ug/L (MOE, 1984a).

The USEPA's drinking water standard for endrin is 1.0 ug/L (USEPA, 1980). The MOE (MOE, 1983) and HWC (HWC, 1980) have MAC's of 0.2 ug/L. These are calculated using the USEPA's ADI of 0.0004 mg/kg body weight (HWC, 1980). Environment Canada's guideline for endrin in a raw water supply is 1.0 ug/L (Environment Canada, 1979). The IJC's objective is 0.002 ug/L (IJC, 1985). The WHO has no guideline.

Endosulfan

Endosulfan is a chlorinated cyclodiene insecticide used in Ontario (MOE, 1984a) on a wide range of insects. It exists as a mixture of two isomers and hydrolyzes slowly in water (Agriculture Canada, 1982).

It is highly toxic to fish (Agriculture Canada, 1982) and for protection of freshwater aquatic life the USEPA criterion is

0.056 ug/L (USEPA, 1980). The MOE suggests an objective of 0.003 ug/L, again for protection of the aquatic habitat (MOE, 1984a).

The most toxic potential effect of endosulfan to man is that of central nervous system toxicity. However, it is not carcinogenic (Sittig, 1981). For the protection of human health for endosulfan toxicity through ingestion of contaminated water and aquatic organisms the USEPA criterion is 74 ug/L (USEPA, 1980).

Mirex

Mirex, or dodecachloropentacyclodecane is a heavily chlorinated cyclo aliphatic hydrocarbon with eight carbons arranged in a cube and 2 additional carbons bonded off opposite edges. It is a very stable insecticide, toxic to grass-feeding insects, especially ants (Agriculture Canada, 1982).

The MOE (MOE, 1984a) reports that Mirex, released into the environment in any concentration can bioaccumulate to levels which are harmful or lethal to organisms. It has set a zero tolerance limit for Mirex to provide long-term protection of aquatic organisms and man.

The only criterion for Mirex found in the sources reviewed is 0.001 ug/L set both by the MOE (MOE, 1984a) and the USEPA (IJC, 1985) for the protection of the aquatic environment.

Methoxylchlor

Methoxychlor, or 2,2-bis-(p-methoxyphenyl)-1,1,1-trichloroethane is an insecticide very closely related to DDT. It has been substituted for DDT since DDT's banning several years ago. It is effective against a wide range of insects affecting fruit, vegetables, forage crops and livestock (Agriculture Canada, 1982) and on domestic animals for fly control (NRC, 1977). It is actively used in Ontario (MOE, 1984a).

Unlike DDT, Methoxychlor does not bioaccumulate in the body fat of animals (Agriculture Canada, 1982). In fact, it is rapidly excreted (Lappenbusch, 1986). There is no evidence that it is carcinogenic (WHO, 1984) and it is not known to produce any harmful effects in humans (Sittig, 1981).

The WHO's ADI is 0.1 mg/kg body weight and their drinking water guideline is 30 ug/L (WHO, 1984). HWC (HWC, 1980) and the MOE (MOE, 1983) have calculated MACs of 0.1 ug/L based on the USEPA's ADI of 0.02 mg/kg body weight (HWC, 1980). The USEPA's interim drinking water standard is 100 ug/L and they have recently proposed a RMCL of 340 ug/L (Lappenbusch, 1986). Environment Canada's guideline is 35.0 ug/L for raw water supplies (IJC, 1985).

DDT-T (DDT, DDE, DDD)

DDT, or 2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane is an insectide used extensively for the control of malaria, typhus, and other insect-transmitted diseases during World War II. After the war it became the prototype for synthetic insecticides and has been used all over the world (Agriculture Canada, 1982).

DDT is very stable and persists in the ecosystem, passing through the food chain for long periods of time (Lappenbusch, 1986). However, it does undergo some complex degradative changes, the dominant of which is dehydrochlorination to form DDE. It is also reductively dechlorinated to DDD. DDE is much less toxic to insects and higher animals than DDD but persists in the environment even longer than DDD.

DDD is much less stable than DDT and DDE and it does not accumulate in animals (NRC, 1977). Because of the persistence it has been banned in the US and Canada for the past decade (Sittig, 1981).

DDD is carcinogenic (Lappenbusch, 1986). Its non-carcinogenic toxicity is moderate, affecting the central nervous system, skin, and the peripheral nervous system. Exposure symptoms include tremors, dizziness, headaches, conversions, and irritation of eyes and skin.

Criteria are given for total residues of DDT, including DDT, DDD and DDE. The WHO has an ADI of 0.005 mg/kg body weight and a guideline of 1 ug/L (WHO, 1984). Based on this ADI a MAC of 30 ug/L has been determined by the MOE (MOE, 1983) and HWC (HWC, 1980).

An objective for DDT plus metobolites of 0.003 ug/L has been set by the MOE (MOE, 1984a) for the protection of the aquatic habitat. The IJC's ambient water quality objective is 0.003 ug/L (IJC, 1985).

The USEPA has listed suggested criteria for other protection of human health and freshwater aquatic life. The following table summarizes the criteria:

	Human* Health (ng/L)	Freshwater Aquatic (ug/L)
DDT	0.024	0.001
DDE	-	1050
DDD	-	0.6

* One in 10^6 increased cancer risk when used as source of drinking water and aquatic food stuffs.

2,4,5,-TP (Silvex)

2,4,5,-TP (Silvex) or 2,4,5-trichlorophenoxypropionic acid is a chlorophenoxy acid herbicide. It is not a carcinogen

(Lappenbusch, 1986), but commercial grades contain TCDD, which is highly toxic, at 0.1 mg/L or less in the commercial product (NRC, 1977).

All criteria from the agencies reviewed are based on health considerations. The MOE (MOE, 1983) and HWC (HWC, 1980) have published MACs of 10 ug/L. The USEPA interim standard is 10 ug/L. Environment Canada's maximum permissible concentration for a raw water supply is 100 ug/L (Environment Canada, 1979).

2,4,5-T

2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) is a herbicide produced by interaction of 2,4,5-trichlorophenol with the sodium salt of monochloroacetic acid (NRC, 1977). It is more stable than 2,4,-D but it does degrade in water (Lappenbusch, 1986), its primary decomposition product being 2,4,5-trichlorophenol (NRC, 1977).

2,4,5-T is rapidly absorbed and excreted by animals, including man (NRC, 1977). However, technical grade 2,4,5-T contains traces of TCDD which is extremely toxic (Lappenbusch, 1986; NRC, 1977). The toxicity of 2,4,5-T is dependent on the degree of contamination by TCDD.

The only criteria for 2,4,5-T found in the review was from Environment Canada, which they have adopted from the 1969 HWC standards and objectives. Their maximum permissible concentration allowed in raw water is 100 ug/L (Environment Canada, 1979).

2,4-D

2,4-Dichlorophenoxyacetic acid (2,4-D) is a chlorophenoxy herbicide used to regulate plant growth (Lappenbusch, 1986). It is actively used in Ontario (MOE, 1984a). 2,4-D is produced commercially by chlorination of phenol to form 2,4-dichlorophenol,

which reacts with monochloroacetic acid to form 2,4-D (NRC, 1977).

2,4-D is not a carcinogen at drinking water levels but does produce adverse health effects, including fatigue, headache, liver damage, and loss of appetite. In water it breaks down primarily to 2,4-diclorophenol about which little toxicological information is available (Lappenbusch, 1986). It is broken down by soil micro-organisms so it does not accumulate and is infrequently found in soil.

Criteria from the sources reviewed are based on health effects. The Ontario MOE ambient water quality objective for 2,4-D is 4.0 ug/L (MOE, 1984a). Their drinking water objective is 100 ug/L (MOE, 1983) as is HWC's MAC (HWC, 1980). These are based on the USEPA's ADI of 0.016 mg/kg body weight (HWC, 1980). The existing USEPA drinking water criterion for 2,4-D is 100 ug/L. They have proposed a RMCL of 70 ug/L.

The WHO has determined an ADI of 0.3 mg/kg body weight for 2,4-D based on toxicity (WHO, 1984). They have calculated a water quality guideline of 100 ug/L. However, some people may be able to taste this substance when concentrations exceed 50 ug/L.

Alachlor

Alachlor, or 2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide is one of several herbicides based on N-substituted acetanilide. It is used as a pre-emergence herbicide in corn and soybean production. This herbicide is actively used in Ontario (MOE, 1984a), particularly in the southwestern region.

Alachlor is only slightly soluble in water. It is reported to be relatively unstable in the aquatic environment and not particularly bioaccumulative.

Alachlor is of concern from a human health perspective because of its recent identification as a probable human carcinogen (EPA Report) and its prevalence in drinking water from shallow ground and surface waters in agricultural areas. As a result, the MOE has established a program to assess the occurrence and extent of alachlor contamination in drinking water.

HWC has established a drinking water guideline of 5 ug/L for alachlor (HWC, 1980). The MOE has been more conservative and established a level of 1 ug/L (MOE, 1983).

Toxaphene

Toxaphene is a synthetic organochlorine insecticide. Technical toxaphene is a complex mixture of 200 chlorinated hydrocarbons based on the chlorination of a natural mixture of camphenes. As a result of its complex nature, little is known of its structure. It is used as a foilage insecticide on a variety of food, feed and fibre crops. Its primary application in the United States is on cotton. Although it is used extensively in the United States replacing many of the agricultural applications of DDT, it is not widely used in Canada.

Like many organochlorine insecticides, toxaphene is relatively persistent in water. Bioaccumulation in fish, algae and insects have been reported (HWC, 1980). The USEPA (USEPA, 1980) has derived a criterion of 0.0013 ug/L for the protection of freshwater aquatic life.

Toxaphene has been detected in some water samples. The concern for human health is its carcinogenic potential. For the protection of human health from the carcinogenic potential of toxaphene, the USEPA (USEPA, 1980) recommends minimizing ambient water concentration. They have estimated a level corresponding to increased cancer risk over a lifetime of one in 10^6. The level

is 0.71 ng/L. Using animal models, HWC has calculated a MAC of 0.024 mg/L in drinking water (HWC, 1980).

Aesthetics are also a concern with toxaphene. Toxaphene can cause taste and odour problems at concentrations as low as 0.0052 mg/L. Therefore, HWC has adjusted its MAC for organoleptic effects and has set it at 0.005 mg/L (HWC, 1980).

Atrazine

Atrazine is one of a class of herbicides derived from s-triazine. It is extensively used as a preemergence herbicide on corn, asparagus, grasses and Christmas trees.

Atrazine is soluble in water and has been detected in surface waters as a result of agricultural runoff. It has a low order of toxicity and is not carcinogenic. It degrades rapidly in the environment. The sources reviewed provided no water quality guidelines for atrazine.

APPENDIX J
MINISTRY OF THE ENVIRONMENT
WELLAND RIVER MONITORING DATA

APPENDIX J
HISTORICAL ANALYTICAL DATA
MINISTRY OF THE ENVIRONMENT
WELLAND RIVER AT SINCLAIRVILLE BRIDGE
AND
THE BRIDGE SOUTH OF WELLAND AIRPORT

The data included in these tables have been collected by the Ministry of the Environment at two points on the Welland River, one upstream and one downstream of the OWMC Preferred Site. The combined data is thus considered approximately representative of conditions of interest in this study. The data have been collected monthly, from 1978 to 1986. The effects of seasonal variations on each parameter can be assessed, as well as the magnitude of unsystematic natural fluctuations in river properties. For each substance analyzed, average, maximum, minimum and standard deviation have been computed. These values can be compared to those found in the present sampling and analytical program.

```
EEEEEEEEE   NN      NN   VV      VV   II   RRRRRRRR    OOOOOOOOO   NN      NN   MM    MM   EEEEEEEEE   NN      NN   TTTTTTTTTT
EEEEEEEEE   NNN     NN   VV      VV   II   RRRRRRRRR   OOOOOOOOO   NNN     NN   MMM  MMM   EEEEEEEEE   NNN     NN   TTTTTTTTTT
EE          NNNN    NN    VV    VV    II   RR      RR  OO      OO  NNNN    NN   MMMMMMMM   EE          NNNN    NN       TT
EEEEEEE     NN NN    NN    VV    VV    II   RRRRRRRRR   OO      OO  NN NN    NN   MM MM MM   EEEEEEE     NN NN    NN       TT
EEEEEEE     NN  NN   NN     VV VV      II   RRRRRRRRR   OO      OO  NN  NN   NN   MM    MM   EEEEEEE     NN  NN   NN       TT
EE          NN   NNNN      VV VV      II   RR    RR    OO      OO  NN   NNNN   MM    MM   EE          NN   NNNN    NN       TT
EEEEEEEEE   NN    NNN       VVV       II   RR     RR   OOOOOOOOO   NN    NNN   MM    MM   EEEEEEEEE   NN    NNN    NN       TT
EEEEEEEEE   NN     NN       VVV       II   RR      RR  OOOOOOOOO   NN     NN   MM    MM   EEEEEEEEE   NN     NN    NN       TT

OOOOOOOOO   NN      NN   TTTTTTTTTT      AAAAA      RRRRRRRR    II   OOOOOOOOO
OOOOOOOOO   NNN     NN   TTTTTTTTTT     AAAAAAA     RRRRRRRRR   II   OOOOOOOOO
OO      OO  NNNN    NN       TT       AA       AA   RR      RR  II   OO      OO
OO      OO  NN NN   NN       TT       AAAAAAAAAA   RRRRRRRRR   II   OO      OO
OO      OO  NN  NN  NN       TT       AAAAAAAAAA   RRRRRRRR    II   OO      OO
OO      OO  NN   NNNN        TT       AA       AA   RR    RR    II   OO      OO
OOOOOOOOO   NN    NNN        TT       AA       AA   RR     RR   II   OOOOOOOOO
OOOOOOOOO   NN     NN        TT       AA       AA   RR      RR  II   OOOOOOOOO
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S A M P L E I N F O R M A T I O N S Y S T E M

DATE OF RUN 1 MAY 87

WATER QUALITY DATA - WELLAND RIVER

" K E E P O N T A R I O B E A U T I F U L "

NOTE: USER MUST ASSUME THE RESPONSIBILITY OF ENSURING THE ACCURACY OF THE REPORTED DATA PRIOR TO INTERPRETATION OR ARRIVING AT ANY CONCLUSIONS AS TO THE MEANING OF THE INFORMATION.

PERKONS IMANTS
W.L. REGION
521-7540

ABBREVIATIONS USED:

BTM GRAB	BOTTOM GRAB SAMPLE
CORE	BOTTOM CORE SAMPLE
CNT LOW	BACTERIA COUNT UNACCEPTABLE
DATA AVL	DATA NOT STORED IN THIS SYSTEM BUT IS AVAILABLE
DC	DEPTH COMPOSITE SAMPLE
DD	DAY
ET	END TIME
EXP	PRECIPITATING AT EXPOSURE (FOR PRECIP. SAMPLES)
GC	GAUGE DEPTH (FOR PRECIP. SAMPLES)
I	DEPTH INTERVAL (IN METERS) WHEN ASSOCIATED WITH DC TIME INTERVAL (IN HOURS) WHEN ASSOCIATED WITH TC
ID	INITIAL DATE (SET-UP DATE FOR PRECIP. SAMPLES)
IT	INITIAL TIME (SET-UP TIME FOR PRECIP. SAMPLES)
LAT	LATITUDE
LONG	LONGITUDE
LMT	LOCAL MEAN TIME
LO1	LOW VOLUME SEQUENTIAL SAMPLE
LO2	LOW VOLUME NUTECH SAMPLE
MM	MONTH
N	NUMBER OF SAMPLES (USED FOR DC, TC AND CORE SAMPLES)
DRY	PRECIPITATION SAMPLE (DRY ONLY)
WET	PRECIPITATION SAMPLE (WET ONLY)
BULK	PRECIPITATION SAMPLE (BULK)
GRND	PRECIPITATION SAMPLE (ON GROUND SNOW COURSE)
REM	PRECIPITATING AT REMOVAL (FOR PC SAMPLES 0,1,2,3)
SD	START DEPTH
ST	START TIME
SED CORE	SEDIMENT CORE SAMPLE (DEPTH FROM AND TO MEASURED IN CM)
SED GRAB	SEDIMENT GRAB SAMPLE (DEPTH FROM AND TO MEASURED IN CM)
WLE	WATER LAYER - WHOLE LAKE COMPOSITE
EPI	WATER LAYER - EPILIMNION ZONE
MET	WATER LAYER - METALIMNION ZONE
HYP	WATER LAYER - HYPOLIMNION ZONE
EUP	WATER LAYER - EUPHOTIC ZONE
GEN	WATER LAYER - GENERAL LAYER
TC	TIME COMPOSITE SAMPLE
TNTC	BACTERIA TOO NUMEROUS TO COUNT
V	VOLUME WHEN ASSOCIATED WITH LO1 AND LO2 SAMPLES
YY	YEAR

NOTE: ONE SAMPLE DESIGNATES DATA ASSOCIATED WITH A LOCATION AT ONE POINT IN TIME

INDIVIDUAL TEST VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

REMARK	MEANING OF REMARK	COMMENT CODE
<	ACTUAL RESULT < THAN REPORTED VALUE	PE
<=>	APPROXIMATE RESULT	
<E	NO RESP.: (EXCESS DIL'N) MIN. VALUE	PE
<N	NON-DETECTED	PE
<R	DETECT LIMIT REPORT: VALUE < LIMIT	PE
<S	TRACE RESP.: < THAN VALUE REPORTED	PE
<T	LOW VALUE TENTATIVE: FOR INFO ONLY	PT
<W	0 VALUE IS MIN. MEASURABLE AMOUNT	PT
|AA	NO DATA: ANAL. REQ ABSENT-AMBIGUOUS	
|AD	NO DATA: ANOMALOUS DATA WITHDRAWN	
|AI	ADDITIONAL INFORMATION AVAIL AT LAB	
|AL	NO DATA: AL NOT DONE, PH > 5.5	
|AM	NO DATA: PH > 7	
|AR	SEE ATTACHED REPT: NO NUMERIC VALUE	
|AW	NO DATA: ANALYSIS WITHDRAWN	
|BC	NO DATA: BACKGRND COLOUR INTERFERES	
|BL	NO DATA: UNRELIABLE BLANK	
|BN	NO DATA: BACKGND TO NUMEROUS TO CNT	
|BT	NO DATA: SAMPLE BROKEN IN TRANSIT	
|CA	NO DATA: CARBONATE NOT DONE, PH>5.0	
|CC	COURT CASE: RESULTS REPT. ELSEWHERE	
|CR	COULD NOT PERFORM CONFIRMING REANAL	
|CS	NO DATA: CONTAMINATION SUSPECTED	
|CU	TYPICAL/TOTAL COLONY CNT UNSUITABLE	
|DD	SAMP. SUBM. AS DUP. FOUND TO DIFFER	
|DI	NO DATA: SAMPLE DISCARDED IN ERROR	

NOE - SAMPLE INFORMATION SYSTEM R4.5 ABBREVIATIONS AND REMARKS USED ON REPORTS DATE OF REPORT: 1 MAY 87

INDIVIDUAL TEST VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

REMARK	MEANING OF REMARK	COMMENT CODE
|EF	NO DATA: LABORATORY EQUIP. FAILURE	
|EP	NO DATA: EXCESS. PRESERVATIVE USED	
|FC	NO DATA: FOIL CAP CONTAMINATED SAMP	
|FF	NO DATA: FIELD FILTERED SAMP REQURD	
|GL	NO DATA: GREEN LABEL REQ ON BOTTLE	
|HB	HIGH BACKGND ABSORBANCE IN EXTRACT	
|HI	RERUN: NO VALUE,OFFSCALE HIGH	
|IC	NO DATA: IMPROPER CONTAINER	
|IF	NO DATA: INVALID FILTER-NO AIR VOL	
|IL	NO DATA: SAMPLE INCORRECTLY LABELED	
|IM	INTERNAL LAB MEMO; FOR LAB USE ONLY	
|IP	NO DATA: INSUFFICIENT PRESERVATIVE	
|IR	INSUFFICIENT SAMP FOR REPEAT ANALY	
|IS	NO DATA: INSUFFICIENT SAMPLE	
|IV	NO DATA: INVALID SAMPLE	
|LA	SAMPLE SPOILED IN LAB ACCIDENT	
|LC	NO DATA: LAB CAPACITY EXCEEDED	
|LD	NO DATA: TEST QUEUED:SAMP DISCARDED	
|LO	RERUN: NO VALUE,OFFSCALE LOW	
|LP	NO DATA: PERISHABLE TEST QUEUE LATE	
|MS	SAMP TOO COMPLEX REFERRED TO MS GRP	
|NA	NO AUTHORIZATION TO PERFORM ANALY	
|NE	SUBM SHEET MISPLACED - NOT ENTERED	
|NF	INFORMATION NOT REC'D FROM SUBMITOR	
|NI	NO DATA: SAMP NOT STORED IN ICE	

MOE - SAMPLE INFORMATION SYSTEM R4.5 ABBREVIATIONS AND REMARKS USED ON REPORTS DATE OF REPORT: 1 MAY 87

INDIVIDUAL TEST VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

REMARK	MEANING OF REMARK	COMMENT CODE
|NP	NO DATA: NO APPROP. PROCEDURE AVAIL	
|NR	NO DATA: SAMPLE NOT RECEIVED AT LAB	
|NS	NO DATA: NOT EQUIP. TO ANALY SAFELY	
|NT	NO DATA: NO TIME RECORDED	
|OC	NO DATA: ORGANIC CARBON CONTENT>17%	
|OF	SLUDGE SAMP DISCARD:BOTTLE OVERFILL	
|OP	NO DATA: OBSCURED PLATE	
|OS	NO DATA: OPTIONAL SAMPLE	
|OT	SAMPLE OVERTITRATD:NO REPEAT POSSBLE	
|PE	PROCEDURE ERROR: SAMP NOW DISCARDED	
|PH	SAMP PH OUTSIDE VALID RANGE	
|PM	NO DATA: PIECE MISSING	
|PR	NO DATA: PRESERVATIVE REQUIRED	
|PU	NO DATA:VSAMPLE PRESUMED UNSTERILE	
|QU	NO DATA: QUALITY CONTROL UNACCEPT.	
|RC	RESULT CHANGED: REPORT REVISED	
|RD	SEE ATTCH. REPT:NO NUM VALUE:DIOXIN	
|RE	NO DATA: SAMP CONTAINER RECV. EMPTY	
|RI	SEE ATTCH. REPT:NO NUM VALUE:ITCS	
|RL	RESULT FORTHCOMING FROM RAD. LAB	
|RM	SEE ATTCH. REPT:NO NUM VALUE:MICRO	
|RN	SEE ATTCH. REPT FOR NUMERIC RESULT	
|RO	SEE ATTCH. REPT:NO NUM VALUE:OTCS	
|RP	SEE ATTCH. REPT:NO NUM VALUE:PEST	
|RR	NO DATA: RERUN HAS BEEN INITIATED	

MOE - SAMPLE INFORMATION SYSTEM R4.5 ABBREVIATIONS AND REMARKS USED ON REPORTS DATE OF REPORT: 1 MAY 87

INDIVIDUAL TEST VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

REMARK	MEANING OF REMARK	COMMENT CODE
|RT	SAMPLE NOT REFRIGERATED IN TRANSIT	
|RW	SEE ATTCH. REPT:NO NUM VALUE:WQS	
|SD	NO DATA: SAMPLE DECOMPOSED	
|SE	SAMPLE EXAMINED: SEE OTHER RESULTS	
|SF	NO DATA: SAMPLE RECEIVED FROZEN	
|SL	NO DATA: SAMP ARRIVED LATE FOR ANAL	
|SM	NO DATA: SAMPLE MISSING:LOST IN LAB	
|SS	SEPARATE SAMP, PROPER. PRESERVE REQ	
|TE	TURB LIMIT OF APP COLOR TEST EXCEED	
|TF	NO DATA: TORN FILTER	
|TH	TURB EXCEEDED RANGE OF INSTRUMENT	
|TN	NO DATA: TOO NUMEROUS TO COUNT	
|TU	NO DATA: ANALY TEMPORARILY UNAVAIL.	
|TW	NO DATA: TARE WT. > LOADED WT.	
|TX	NO DATA: TIME LIMIT EXPIRED	
|J	UNSUITABLE FOR ANALYSIS	
|UB	BROKEN SAMPLE CONTAINER	
|UD	INSUFFICIENT SAMPLE	
|UE	NO DATA: UNCORRECTABLE ERROR	
|UI	NO DATA: UNDETERMINED INTERFERENCE	
|UR	NO DATA: UNPRESERVED SAMP REQUIRED	
|VE	INSUFFICIENT SAMP:VISUAL EST:RSP<15	
|VU	NO DATA: VALUES USED IN CALC UNVAIL	
|WP	NO DATA: WRONG PRESERVATIVE USED	
|12	NO DATA: SAMPLE AGE EXCEEDS 12HR	

INDIVIDUAL TEST VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

REMARK	MEANING OF REMARK	COMMENT CODE
172	NO DATA: SAMPLE AGE EXCEEDS 72HR	
1BT	NO DATA: SAMPLE BROKEN IN TRANSIT	
>	ACTUAL RESULT > THAN REPORTED VALUE	PE
>SF	ACTUAL MASS > SIZED FIBRE MASS	PE
A>	APROX RSLT:EXCEED NORMAL RNGE LIMIT	
AAI	ADDITIONAL INFO AVAILABLE FROM LAB	
AID	APPROX VALUE: INSUFFICIENT DILUTION	
AIP	ANALYSIS IN PROGRESS	
ALO	TOO ORGANIC/4:1 SOL'N:SOIL RATIO	
APD	ANALYSIS PERFORMED AT DORSET LAB	
BPS	RESULTS BIASED LOW DUE TO LONG STOR	
C	BACKGROUND COUNT TO NUMEROUS	
CIC	POSSIBLE CONTAM DUE TO IMPROPER CAP	
CMS	IDENTITY CONFIRMED BY GC/MASS SPEC	
CRO	CALCULATED RESULT ONLY	
DCC	SAMPLE KNOWN TO CONTAIN CARCINOGENS	
DCN	SAMPLE KNOWN TO CONTAIN CYANIDE	
DCP	DANGEROUS CONSTITUENTS PRESENT	
DUP	DUPLICATE	
E	ESTIMATED OR COMPUTED VALUE STORED	
EBR	NO RESULT: BOTTLE RECEIVED EMPTY	
EDC	EXCEEDS 1978 DRINK WATER QUAL CRIT	
EV	ESTIMATED VALUE - TARE WT UNVAIL.	
FAN	FRACTION ANALY: NON-AQUEOUS PHASE	
FAP	FRACTION ANALY: PARTICULATE ONLY	

INDIVIDUAL TEST VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

REMARK	MEANING OF REMARK	COMMENT CODE
FSA	LAB STAFF:FILT.WHOLE SAMP BEFORE AN	
HRF	SUSPECTED HIGH RESULT:IRON PRECIP	
LPI	LABELS PROBABLY INTERCHANGED	
M	MANUALLY ANALYSED	
NAF	NOT ALL REQUIRED TESTS FOUND	
NED	NOT ENOUGH DATA	
NNN	NOTE: CORRECTED VALUE	
NSS	NO SUITABLE SAMPLE	
NTR	NO TIME RECORDED: ANAYL. PERFORMED	
PFS	TEST PERFORMED ON PREV FROZEN SAMP	
PHA	PH ADJUSTED BEFORE ANALYSIS	
PLD	PASSIVE LOADING	
PNF	TEST PERFORMED ON NON-FROZEN SAMPLE	
PNS	TEST PERFORMED ON UNPRESERVE SAMPLE	
PPS	TEST PERFORMED ON PRESEVERED SAMPLE	
P52	PCB RESEM.MIX AROCLR 1242 1245 1260	
P20	PCB RESEMBLED MIX AROCLOR 1242 1260	
P21	PCB RESEMBLED AROCLOR 1221	
P24	RESEMBLED MIX: AROCLOR 1242 AN 1254	
P28	RESEMBLED MIX: AROCLOR 1242 AN 1248	
P40	RESEMBLED MIX: AROCLOR 1254 AN 1260	
P42	PCB RESEMBLED AROCLOR 1242	
P48	PCB RESEMBLED AROCLOR 1248	
P54	PCB RESEMBLED AROCLOR 1254	
P60	PCB RESEMBLED AROCLOR 1260	

INDIVIDUAL TEST VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

REMARK	MEANING OF REMARK	COMMENT CODE
P54	RESEMBLED MIX: AROCLOR 1248 AN 1254	
R24	REPEAT: 24HR BETWEEN SAMP AND ANAL	
R48	REPEAT: 48HR BETWEEN SAMP AND ANAL	
R72	REPEAT: 72HR BETWEEN SAMP AND ANAL	
SD	SAMP SUBM AS DUPLIC FOUND TO DIFFER	
SIL	SAMP INCORRECTLY LABELLED	
SPH	SATURATED PASTE PH REPT:HIGH ORGAN.	
SPL	SEVERAL PEAKS,LARGE,NOT PRIORITY	
SPS	SEVERAL PEAKS,SMALL,NOT PRIORITY	
STA	SAMP TOO OLD FOR RE-ANALYSIS	
STC	SAMP TOO COMPLEX FOR THIS METHOD	
TAF	TRACE AMOUNT FOUND	
U	UNRELIABLE RESULT	
URD	RESULT MAY BE LOW: UNDISOLVE PART.	
WSB	WARNING-HEAVY SILT IN SAMP BIAS RES	
WSD	WRONG SAMP DESCRIPTION ON BOTTLE	
WST	WET SAMP MASS USED:RESLT REPT MG/KG	
X1	DILUTD BY 10 DETECT LIMT 10X NORM	
X2	DILUTD BY 100 DETECT LIMT 100X NORM	
X3	DILUTD BY 1000 DECT.LIMT 1000X NORM	
24P	P-A BOTTLE POSITIVE AFTER 24 HOURS	
48P	P-A BOTTLE POSITIVE AFTER 48 HOURS	
72P	P-A BOTTLE POSITIVE AFTER 72 HOURS	
96P	P-A BOTTLE POSITIVE AFTER 96 HOURS	
99P	P-A BOTTLE POSITIVE AFTER 120 HOURS	

COMPUTED VALUES MAY BE QUALIFIED BY ONE OF THE FOLLOWING REMARKS:

<1 VALUE WITH A REMARK WHICH HAS A COMMENT CODE OF PT (AS ABOVE) USED IN COMPUTATIONS

NOTE: VALUES WITH COMMENT CODE OF PE ARE NOT USED IN COMPUTATIONS

REMARK CODES APPEAR TO THE RIGHT OF THE VALUE I.E. 435.55<T

S.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 54 19.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4753650.0 4 REGION: 02 DISTANCE: 55.455

**INTERIM TEST-NAME:			FWSADP	FSPROJ	ACDT	ALKT	ALUT	ASUT	BOD5	CAU2	CLIDUR	COD
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	SAMPLE DEPTH M	PROJECT SUB-PROJ CODE	ACIDITY TOTAL MG/L AS CACO3	ALK TOTAL MG/L AS CACO3	ALUMINUM UNF.TOT. MG/L AS AL	ARSENIC UNF.TOT. MG/L AS AS	5 DAY BOD TOT.DEM. MG/L AS O	CALCIUM UNF.REAC MG/L AS CA	CHLORIDE UNF.REAC MG/L AS CL	CHEM. OX DEMAND MG/L AS O
780202	1050	38339	0.50	0101	17.200	114			1.5	52.000	25.000	71
780301	1200	38337	0.50	0101	15.470	139			0.3	63.000	28.000	53
780322	1555	38427	0.50	0101	8.320	33			3.5	14.000	7.600	43
780420	1040	38467	0.50	0101	2.32	95			1.0	44	16.5	50
780525	1005	38509	0.50	0101	1.910	122			1.5	55.000	24.500	62
780619	0750	38549	0.50	0101	3.940	95			1.4	59.000	24.500	41
780710	1140	38591	0.50	0101	2.870	133			1.0	60.000	24.000	46
780828	1035	38634	0.50	0101	2.590	132			1.5	10.000	40.000	55
780911	1340	38675	0.50	0101	1.200	133			0.4	64.000	39.000	45
781031	1010	38713	0.50	0101	6.39	135			1.5	53	20.0	54
781128	1100	38735	0.50	0101	5.72	93			2.5	47	22.5	53
781212	1025	38776	0.50	0101	5.47	82			1.0	45	17	51
790110	1100	48319	0.50	0101					1.5		12.500	61
790226	1210	48355	0.50	0101					4.0		15.000	43
790308	1059	48403	0.50	0101					2.0		7.100	30
790418	1130	48466	0.50	0101					2.0		12.500	40
790509	1005	48530	0.50	0101					2.4		19.000	42
790620	1120	48559	0.50	0101					1.5		20.5	52
790718	1155	48619	0.50	0101					1.5		22.000	25
790827	1102	48649	0.50	0101					1.5		22.500	19
790917	1355	48652	0.50	0101		95			1.0		19.000	46
791015	1140	48751	0.50	0101					1.5		31.500	33
791122	1025	48792	0.50	0101					1.4		27.500	44
791227	1155	48834	0.50	0101					2.4		15.0	44
800130	1110	28339	0.50	0101					2.0		19.000	54
800227	1200	28374	0.50	0101					5.0		38.500	50
800319	1100	28399	0.50	0101					4.5		25.000	70
800415	1110	28455	0.50	0101					1.5		12.500	53
800506	1200	28503	0.50	0101					2.0		14.500	52
800609	1100	28591	0.50	0101					1.5		17.500	44
800706	1430	80028	0.50	0101								
800707	0205	80029	0.50	0101								
800715	1050	28595	0.50	0101					1.5		22.500	45
800811	1055	28644	0.50	0101					1.0		25.000	44
800908	1020	28694	0.50	0101					1.2		33.500	55
801007	1035	28738	0.50	0101					1.0		43.000	52
801117	1050	28787	0.50	0101					1.2		29.500	45
801217	1025	28826	0.50	0101					2.2		22.000	54
810122	1215	38332	0.50	0101					1.4		28.000	49
810309	1035	38403	0.50	0101							25.00	

(CONTD)

S.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 59 19.79 LONG: 079 19 05.45 U T M: 17 0557150.0 4759850.0 4 REGION: 02 DISTANCE: 55.455

*=INTERIM TEST-NAME:		FWSACP	FGPROJ	ACDT	ALKT	ALUT	ASUT	BOD5	CAUR	CLIDUR	COD
SAMPLE DATE YYMMDD	HOUR LAT	SAMPLE NUMBER	SAMPLE DEPTH M	PROJECT SUB-PROJ CODE	ACIDITY TOTAL MG/L AS CACO3	ALK TOTAL MG/L AS CACO3	ALUMINUM UNF.TOT. MG/L AS AL	ARSENIC UNF.TOT. MG/L AS AS	5 DAY BOD TOT.DEM. MG/L AS O	CALCIUM UNF.REAL MG/L AS CA	CHLORIDE UNF.REAC MG/L AS CL	CHEM. OX DEMAND MG/L AS O
810423	1105	33490	0.30	0101							55.00	
810513	1005	33521	0.30	0101							20.50	
810611	1000	33565	0.30	0101							21.00	
810728	1035	33603	0.30	0101							29.50	
810825	1505	33675	0.30	0101							40.00	
810924	1200	33707	0.30	0101							30.00	
811008	1115	33754	0.30	0101							31.50	
811130	1000	33837	0.30	0101							22.00	
820121	1205	43341	0.30	0101	75				55.0	16.50		
820204	1140	43359	0.30	0101	112				52.0	25.00		
820311	1025	43436	0.30	0101	102.0				35.0	18.50		
820415	0955	43493	0.30	0101	79.5				37.5	13.00		
820513	1005	43571	0.30	0101	104.5				50.4	25.00		
820622	1105	43614	0.30	0101	87.5				45.5	22.00		
820706	1205	43659	0.30	0101	105.9				50.1	25.00		
820809	1115	43712	0.30	0101	122.5				50.1	25.80		
820902	1045	43831	0.30	0101	151.5				49.2	28.50		
821005	1055	43842	0.30	0101	145.1				54.0	36.50		
821104	1025	43902	0.30	0101	119.7				63.1	45.40		
821209	1020	43956	0.30	0101	83.5				42.5	17.20		
830105	0950	23511	0.30	0101	73.4				33.7	13.40		
830210	1040	23556	0.30	0101	52.2				32.2	13.00		
830308	1050	23615	0.30	0101	91.1				43.2	20.60		
830406	1030	23650	0.30	0101	81.7				39.3	14.30		
830502	1010	23723	0.30	0101	99.4				43.2	17.20		
830616	1025	23773	0.30	0101	113.7				44.5	19.60		
830704	1235	23819	0.30	0101	120.5				55.5	22.70		
830810	1015	23853	0.30	0101	84.8				53.5			
830901	1055	23908	0.30	0101	114.7				45.2	18.50		
831004	1030	23953	0.30	0101								
831102	1140	23958	0.30	0101								
831205	0950	23804	0.30	0101						40.05		29.7
840104	1025	64711	0.30	0101	73.4				41.9	19.12		
840202	1235	64760	0.30	0101	83.4				43.10	28.43		
840306	1040	64801	0.30	0101	135.4				53.00	31.25		32.9
840409	1035	64850	0.30	0101	85.5				43.00	24.35		17.2
840507	1050	64922	0.30	0101	52.9				25.90	13.63		30.5
840604	1025	65053	0.30	0101	119.5				53.10	27.15		40.5
840703	1020	65113	0.30	0101	120.7				47.30	17.34		
840813	1030	65177	0.30	0101	99.4	5.900	0.001	5.52		15.41		63.3
										20.24		65.3

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET COD-: 02
004
5400

LAT: 42 58 18.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4758850.0 4 REGION: 02 DISTANCE: 55.555

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	SAMPLE DEPTH M	PROJECT SUB-PROJ CODE	ACDT ACIDITY TOTAL MG/L AS CACO3	ALKT ALK TOTAL MG/L AS CACO3	ALUT ALUMINUM UNF.TOT. MG/L AS AL	ASUT ARSENIC UNF.TOT. MG/L AS AS	BOD5 BOD 5 DAY TOT.DEM. MG/L AS O	CAUR CALCIUM UNF.REAC MG/L AS CA	CLIDUR CHLORIDE UNF.REAC MG/L AS CL	COD CHEM. OX DEMAND MG/L AS O
840912	1255	65207	0.50	0101		133.4				54.70	26.84	31.0
841010	1345	65252	0.50	0101		110.5				51.50	25.50	39.4
841108	1050	65305	0.50	0101		143.1				57.10	36.41	27.2
841203	1105	65352	0.50	0101							26.56	37.9
850102	1015	34717	0.50	0101		59.6				53.20	16.24	41.3
850204	1045	34761	0.50	0101							35.85	35.2
850306	1040	34808	0.50	0101		69.9				55.50	20.85	30.3
850401	1135	34852	0.50	0101							15.75	53.0
850506	1115	34930	0.50	0101		115.6				51.05	24.60	37.2
850605	1340	34980	0.50	0101		133.7				61.55	32.55	
850716	1125	35073	0.50	0101		134.5				53.20	32.65	25.5
850820	1135	35097	0.50	0101							31.15	22.9
850911	1055	34805	0.50	0101		127.4				73.50	67.75	25.2
851009	1050	34850	0.50	0101							35.25	31.9
851112	1200	34912	0.50	0101		75.8	6.200		7.10<=>		14.45	40.9
851204	1250	34949	0.50	0101							17.70	37.7
860106	1050	24713	0.50	0101		140.2				61.50	35.80	34.5
860205	1150	24840	0.50	0101							24.10	41.7
860303	1050	24997	0.50	0101		85.5				55.50	37.80	35.3
860414	1015	24955	0.50	0101							25.30	42.5
860505	1015	25011	0.50	0101		101.4				55.70	18.50	42.2
860612	1035	25061	0.50	0101							20.90	
860707	1125	25119	0.50	0101		140.7				61.70	31.50	40.2
860805	1100	25151	0.50	0101							43.00	33.4
860911	1105	25209		0101		137.5				53.10	30.80	24.1
		MAXIMUM	0.50		17.200	143.1	6.200	0.001	7.10	73.50	35.25	55
		ARITH MEAN	0.50		5.93	106	5.050	0.001	2.0	45	26	44
		GEOM MEAN			4.30	102	4.917		1.7	45	24	42
		MINIMUM	0.30		1.200	39	3.900	0.001	0.4	10.000	7.100	17.2
		STD DEV (GEOM *)			5.29	25	1.626		1.2	13	12	14
		# SAMP IN STATISTICS	104		12	57	2	1	54	54	121	67
		% SAMP (EXCLUDED)										

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 54 19.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4753850.0 4 REGION: 02 DISTANCE: 55.555

*=INTERIM TEST-NAME:		COLAP	CONDAM	CONDZS	COUT	DO	DOC	FCMF	FEUT	FSMF	PWPH
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	COLOUR APPARENT PCU	CONDUCT. AMBIENT UMHO/CM AMBIENT	CONDUCT. 25C UMHO/CM AT 25 C	COPPER DVF.TOT. MG/L AS CU	DISOLVED OXYGEN MG/L AS O	CARBON DISOLVED ORGANIC MG/L AS C	FECAL COLIFORM MF CNT /100ML	IRON DVF.TOT. MG/L AS FE	FECAL STREPTOS MF CNT /100ML	PH FIELD
780202	1050	38339	70.000>		452.0		3.5		190	1.700	710	
780301	1200	38337	70.000>		525.0		5.3		520	2.700	230	
780322	1555	38427			138.0		3.7		220	6.000	1270	
780420	1040	38457	70 >		355		10.0		50	6.40	340	
780525	1005	38539	70.000>		474.0		11.2		20	2.500	28	
780619	0950	38549	208.000		465.0		5.4		36	2.750		
780710	1140	38591	195.000		455.0		5.4		20	4.200	55	
780828	1035	38634			580.0		9.5		24	1.520	35	
780911	1540	38675	39.000		560.0		5.5		4	1.150	20	
781031	1010	38713	222		475		7.9		203	2.1	228	
781128	1100	38756	195		430		7.5		420	3.2	580	
781212	1025	38776	330		365		11.2		1300	5.0	1120	
790110	1100	43519	265.000		270.0		7.5		220	5.300	2540	
790226	1210	43363	155.000		150.0		10.5		500AID	5.300	2600	
790308	1059	43403	225.000		140.0		10.2		130<	5.300	1300	
790418	1130	48456	340.000		248.0		7.5		90AID	12.000	700AID	
790509	1005	43530	105.000		405.0		10.7		20AID	1.400	20<	
790620	1120	43559	140		420		7.2		40AID	3.3	20AID	
790718	1135	48619	105.000		375.0		5.2		50AID	3.000	10AID	
790827	1102	43649	7.000		333.0		5.5		10AID	0.370	20AID	
790917	1035	43662	155.000		435.0		4.7		1300	2.300	370	
791015	1140	48751	145.000		550.0		8.1		950	2.600	1050	
791122	1025	43792	150.000		540.0		9.7		130<	2.500	230AID	
791227	1135	43854	630		242		10.0		1120	2.500	5000>	
500130	1110	23339	65.000		365.0		3.3		40AID	9.300	450	
500227	1200	23374	52.000		570.0		5.5		230	1.500	1600	
500319	1100	23399	70.000>		310.0		10.5		420	4.400	5000>	
500415	1110	23455	70.000>		315.0		10.1		1500	16.000	10500	
500506	1200	23503	70.000>		345.0		7.3		35	4.700	60	
500609	1100	23581	70.000>		430.0		5.4		550	4.400	800	
500706	1430	80028			435.0		5.9					
500707	0205	80029			485.0		5.9					
500715	1050	23596			455.0		5.7		700	5.900	40	7.6
500811	1055	23644	70.000>		500.0		6.9		20AID	5.900	50AID	7.9
500908	1020	23674	54.000		570.0		7.5		10AID	1.300	20AID	7.1
501007	1035	23739	70 >		640.0		5.4		530	1.900	50AID	7.4
501117	1050	23787	70 >		455.0		10.5		45	2.5000	500	7.45
501217	1025	23825	70.000>		430.0		10.3		130	5.1000	800	7.5
510122	1215	38552	70.000>		550.0		4.5		470	4.2000	150	7.0
510509	1035	33433			420		11.60					7.20

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 54 19.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4753850.0 4 REGION: 02 DISTANCE: 35.353

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	COLAP COLOUR APPARENT HZU	CONDAM CONDUCT. AMBIENT UMHO/CM AMBIENT	COND25 CONDUCT. 25C UMHO/CM AT 25 C	CUUT COPPER UNF.TOT. MG/L AS CU	DO DISOLVED OXYGEN MG/L AS O	DOC CARBON DISOLVED ORGANIC MG/L AS C	FCMF FECAL COLIFORM MF CNT /100ML	FEUT IRON UNF.TOT. MG/L AS FE	FSMF FECAL STREPTOS MF CNT /100ML	PHPH PH FIELD
810423	1105	38480					10.20					7.90
810513	1005	38521					9.20					7.20
810611	1000	38565					5.00					7.40
810728	1035	38603					4.70					
810825	1505	38675					8.20					
810924	1200	38707					7.10					7.65
811008	1115	38754					9.00					7.95
811130	1000	38837					11.50					7.50
820121	1205	48341					13.20					6.40
820204	1140	48358					4.30					7.35
820311	1025	48436					1.30					6.70
820415	0955	48493					9.80					6.95
820513	1005	48571					10.20					7.80
820622	1105	48614					10.40					7.65
820706	1205	48659					9.0					8.20
820809	1115	48712					5.70					7.50
820902	1045	43801					5.00					7.90
821005	1055	49842					7.30					7.50
821104	1025	49902					7.10		1150		5000>	7.30
821209	1020	48956					8.90		530		1520	7.75
830105	0950	23511					9.80		400		420	7.40
830210	1040	23558					5.50					7.15
830306	1050	23615					9.40		60<=>		550	7.75
830406	1030	23650					7.80					7.75
830502	1010	23723					5.40		820		9700	7.65
830616	1025	23773					7.30					7.90
830704	1235	23818					5.20		50<=>		50<=>	7.50
830810	1015	23863					4.70					7.55
830901	1355	23908					5.50		50<=>		40<=>	7.70
831004	1030	23953					7.90					8.00
831102	1140	23758			599.0		10.40	9.9	20<=>		20<	7.90
831205	0950	23804					11.80					7.45
840104	1025	64711					3.50		120<=>		120<=>	7.10
840202	1235	64750			640.0		9.40	9.5				7.80
840306	1040	64801			409.0		12.20	9.3	50<=>		40<=>	
840409	1035	64850			243.0		10.30	11.4				7.50
840507	1050	64922			483.0		9.80	14.7	220		20<=>	
840604	1025	65053		335			5.00					8.00
840703	1020	65113		345	352.0	0.005	4.60		200	5.700	20<=>	7.85
840813	1030	65177		365	416.0		5.00	12.1				7.80

(C O N T D)

MOE - SAMPLE INFORMATION SYSTEM R4.5 STATION DETAIL REPORT DATE OF REPORT: 1 MAY 87 PAGE: 0

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02 004 5400

LAT: 42 58 18.79 LONG: 079 19 05.45 U T M: 17 0637150.0 4758850.0 4 REGION: 02 DISTANCE: 56.855

*=INTERIM TEST-NAME: COLAP CONDAM COND25 COUT DO DOC FCMF FEUT FSMF FWPH

SAMPLE DATE YYMMDD	HOUR LAT	SAMPLE NUMBER	COLOUR APPARENT HZU	CONDUCT. AMBIENT UMHO/CM AMBIENT	CONDUCT. 25C UMHO/CM AT 25 C	COPPER UNF.TOT. MG/L AS CU	DISOLVED OXYGEN MG/L AS O	DISOLVED ORGANIC CARBON MG/L AS C	FECAL COLIFORM MF CNT /100ML	IRON UNF.TOT. MG/L AS FE	FECAL STREPCOCUS MF CNT /100ML	PH FIELD
840912	1255	65207		425	435.0		6.90	11.9	1000		350	7.75
841010	1345	65252		555	446.0		4.70	11.7				8.00
841108	1050	65305		380	562.0		3.30	9.7	1140		850	8.25
841203	1105	65352		500	535.0		10.10	5.4				8.05
850102	1015	34717		155	312.0		10.30	11.3	1300		4100	7.75
850204	1045	34761		285	595.0		7.30	11.3				7.90
850306	1040	34808		145	310.0		8.50	9.0	500<=>		500<=>	7.50
850401	1135	34852		150	269.0		9.70	11.1				7.80
850506	1115	34930		330	441.0		7.80	11.9	20<=>		20<	8.00
850605	1340	34930		435			6.70					7.90
850716	1125	35073		465	513.0		6.20	9.0	40<=>		20<=>	7.55
850820	1135	35097			456.0		7.80	5.3				8.05
850911	1055	34805			733.0		7.20	9.2	100<=>		50<=>	7.90
851009	1050	34850			807.0		9.60	4.3				8.05
851112	1200	34912			302.0	0.006	9.30		2700	6.000	1940	7.50
851204	1250	34949			308.0		10.40	11.1				8.20
860106	1050	24713			527.0		6.50	11.4	50<=>		40<=>	7.70
860205	1150	24840			345.0		5.90	11.7				7.80
860303	1050	24997			429.0		7.20	10.3	50<=>		20<=>	7.95
860414	1015	24953			422.0		9.40	14.8				7.75
860505	1015	25011			352.0		8.90	13.7	20<		20<	8.10
860612	1055	25051			403.0		5.40	15.0				7.50
860707	1125	25119			504.0		6.70	14.7	350		10<	8.20
860806	1100	25151		550	560.0		7.50	12.0				8.20
860911	1105	25209			453.0		7.40	9.5	210		50<=>	
	MAXIMUM		650	550	807.0	0.006	13.20	15.0	2700	16.000	10600	8.25
	ARITH MEAN		190	335	438	0.005	8.1	10.9	379	4.3	919	7.7
	GEOM MEAN			312	417	0.005	7.5	10.7		3.5		7.5
	MINIMUM		7.000	145	138.0	0.005	1.30	5.4	4	0.890	10	6.40
	STD DEV (GEOM *)			117	127	0.001	2.1	2.4		3.1		0.4
	# SAMP IN STATISTICS		21	15	71	2	105	29	59	39	55	58
	% SAMP (EXCLUDED)		38						4		15	

(CONTD)

MOE - SAMPLE INFORMATION SYSTEM R4.5 STATION DETAIL REPORT DATE OF REPORT: 1 MAY 87 PAGE: 7

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 58 18.79 LONG: 079 19 35.45 U T M: 17 0557150.0 4759950.0 4 REGION: 02 DISTANCE: 55.555

*=INTERIM TEST-NAME: FWSTRC FWTEMP HARDT IONCAL KKUP MGUR MNUT NAUR NIUT NNHTFR

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	STREAM COND.	WATER TEMP DEG.C	HARDNESS TOTAL MG/L AS CACO3	ION BALANCE CALC.	POTASSIUM UNF.REAC MG/L AS K	MAGNESIUM FIL.REAC MG/L AS MG	MANGANESE UNF.TOT. MG/L AS MN	SODIUM UNF.REAC MG/L AS NA	NICKEL UNF.TOT. MG/L AS NI	NH3-N TOTAL FIL.REAC MG/L AS N
780202	1050	33339	4	2.0	187.000		4.95	14.000	0.245	15.000		0.304
780301	1200	33387	4	0.5	227.000		4.90	17.000	0.530	17.000		0.283
780322	1555	33427	3 Y	2.2	56.000		4.20	4.650	0.130	4.000		0.440
780420	1040	33467	3	9.0	165		7.5	13.5	0.130	10.2		0.104
780525	1005	33509	6	20.0	217.000		5.05	17.500	0.102	14.000		0.115
780619	0950	33549	6	21.0	213.000		5.80	16.000	0.210	13.000		0.125
780710	1140	33591	6	24.0	214.000		6.00	15.500	0.110	13.000		0.054
780828	1035	33634	8	23.0	259.000		5.60	20.50	0.140	21.000		0.030
780911	1340	33675	8	22.0	236.000		5.45	13.500	0.055	22.000		0.014
781031	1010	33713	6	8.9	223		6.6	15	0.038	11		0.045
781128	1100	33738	6	1.3	188		7.8	16	0.074	10		0.125
761212	1025	33776	4	1.2	159		8.0	12.5	0.050	9.0		0.073
790110	1100	43319	4	0.6					0.035			0.075
790226	1210	43363	4	2.2					0.145			0.530
790308	1059	46403	4	1.0					0.110			0.165
790418	1130	43456	3	3.3					0.135			0.114
790509	1005	43530	6	17.0					0.054			0.062
790620	1120	43569	6	22.0					0.160			0.074
790718	1135	48619	6	26.0					0.106			0.082
790827	1102	43649	6	21.2					0.030			0.600
790917	1035	48692	6	15.0					0.036			0.110
791015	1140	43751	6	3.3					0.059			0.065
791122	1025	48792	6	9.0					0.050			0.094
791227	1135	43854	3	3.5					0.158			0.126
800130	1110	28339	4	1.1					0.096			0.522
800227	1200	28374	4	1.0					0.153			0.312
800319	1100	28399	4	2.4					0.130			0.910
800415	1110	28455	3	7.0					0.190			0.150
800506	1200	28503	3	16.0					0.140			0.110
800609	1100	28531	6	15.5					0.155			0.195
800706	1430	60025	6	25.0								0.123
800707	0205	50029	6	23.0								0.141
800715	1050	23596	6	25.0								0.094
800811	1055	23644	6	25.0					0.117			0.024
800908	1020	28694	6	23.5					0.054			0.022
801007	1035	28738	6	10.0					0.050			0.105
801117	1050	28787	6	5.5					0.070			0.116
801217	1025	28826	4	1.0					0.110			0.224
810122	1215	33352	4	0.2					0.100			0.410
810309	1035	33403	3	3.3								0.213

(CONTD)

D.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 55 19.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4755850.0 4 REGION: 02 DISTANCE: 55.555

**INTERIM TEST-NAME:			FWSTRC	FWTEMP	HARDT	IONCAL	KKUR	MGUR	MNUT	NAUR	NIUT	NNHTPR
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	STREAM COND.	WATER TEMP DEG.C	HARDNESS TOTAL MG/L AS CACO3	ION BALANCE CALC.	POTASSIUM UNF.REAC MG/L AS K	MAGNESIUM FIL.REAC MG/L AS MG	MANGANESE UNF.TOT. MG/L AS MN	SODIUM UNF.REAC MG/L AS NA	NICKEL UNF.TOT. MG/L AS NI	NH3-N TOTAL FIL.REAC MG/L AS N
810423	1105	38430	3	11.0								0.124
810513	1005	38521	5	13.0								0.102
810611	1000	38555	5	21.0								0.010
810728	1035	38603	8	21.5								0.012
810825	1505	38675	8	23.5								0.005
810924	1200	38707	5	12.5								0.003
811008	1115	38754	5	8.2								0.014
811130	1000	38837	8	1.0								0.082
820121	1205	43341	4	2.0	137		7.30	12.00	5.7			0.163
820204	1140	43358	4	1.5	200		7.40	17.00	15.0			0.254
820311	1025	43436	4	3.5	125.0		1.40	3.50	10.4			0.014
820415	0955	43493	5	7.5	144.0		5.25	12.10	10.4			0.005
820513	1005	43571	8	18.5	157.0		5.00	14.30	13.50			0.005
820622	1105	43614	8	19.0	178.0		6.15	14.90	12.10			0.005
820706	1205	43659	8	25.0	151.0		5.54	13.60	15.50			0.005
820809	1115	43712	3	24.0	151.0		4.55	13.60	15.90			0.005
820902	1045	43601	5	20.0	182.0		4.72	14.40				0.005
821005	1355	43842	5	16.5	232.0		6.12	17.50	19.30			0.004<T
821104	1325	43902	5	12.0	249.0		8.40	19.10	21.40			0.005
821209	1020	43965	3	3.5	153.0		11.40	13.70	9.70			0.020
830105	0950	23511	4	1.5	136.0		11.30	11.50	5.50			0.0300
830210	1040	23558	4 5	0.5	125.0		10.20	10.90	7.50			0.020
830308	1050	23615	3	3.0	155.0		5.20	15.60	12.70			0.008
830406	1030	23650	3	8.5	152.0		6.36	12.70	9.75			0.014
830502	1010	23723	3	14.0	161.0		7.25	12.90	12.00			0.0150
830616	1025	23773	8	25.0	170.0		4.46	14.20	12.50			0.010
830704	1235	23818	8	27.0	200.0		7.60	16.10	12.40			0.016
830810	1015	23863	8	24.0	145.0		7.96	11.70	7.90			0.003
830901	1055	23908	8	25.0	172.0		7.85	13.30	10.70			0.040
831004	1030	23953	3	14.0								
831102	1140	23758	3	10.5								
831205	0950	28804	3	5.5	167.0		9.86	15.20	9.40			0.145
840104	1025	64711	4	3.0	165.0		7.00	13.90	15.30			0.122
840202	1235	64760	4	1.0	224.0		6.15	16.30	31.40			0.275
840306	1040	64801	4	1.5	161.0		4.53	13.30	13.30			0.760
840409	1035	64850	3	5.5	198.0		9.70	9.90	7.50			0.242
840507	1050	64922	3	13.0	210.0		5.04	17.00	15.20			0.222
840604	1025	65063	8	19.0	174.0		4.82	13.50	12.50			0.103
840703	1020	65113	8	24.0							0.005	0.050
840813	1030	65177	3	24.5								0.085
												0.114

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
0104
5400

LAT: 42 55 18.79 LONG: 079 19 05.45 U T M: 17 0557150.0 4753850.0 4 REGION: 02 DISTANCE: 36.355

*=INTERIM TEST-NAME:			FWSTRC	FWTEMP	HARDT	IONCAL	KKUR	MGUR	MNUT	NAUR	NIUT	NNMTPR
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	STREAM COND.	WATER TEMP DEG.C	HARDNESS TOTAL MG/L AS CACO3	ION BALANCE CALC.	POTASSIUM UNF.REAC MG/L AS K	MAGNESIUM FIL.REAC MG/L AS MG	MANGANSE UNF.TOT. MG/L AS MN	SODIUM UNF.REAC MG/L AS NA	NICKEL UNF.TOT. MG/L AS NI	NH3-N TOTAL FIL.REAC MG/L AS N
840912	1255	65207	3	22.5	195.0		6.44	14.20		15.00		0.046
841010	1345	65252	8	16.0	189.0		6.85	14.50		15.50		0.202
841108	1050	65305	8	9.0	205.0		7.14	14.50		21.10		0.200
841203	1105	65352	3	4.0								0.360
850102	1015	34717	3	3.5	127.0		9.24	10.60		7.35		0.143
850204	1045	34761	4	1.5								0.290
850306	1040	34808	4	2.0	121.0		4.25	9.05		10.90		0.403
850401	1135	34862	3	5.5								0.242
850506	1115	34930	3	15.0	193.0	NE YET	5.07	15.90		15.76		0.104
850605	1340	34980	8	21.0	221.0	NE YET	5.62	15.27		13.00		0.222
850716	1125	35073	8	24.0	211.0	NE YET	4.95	15.90		14.14		0.012
850820	1135	35097	3	23.0								0.094
850911	1055	34205	3	20.5	294.00	NE YET	6.460	24.300		35.50		0.090
851009	1050	34850	3	14.0								0.072
851112	1200	34912	3	7.0								0.053
851204	1250	34949	3	1.0								0.108
860106	1050	24713	4	1.0	224.00	NE YET	5.050	17.000		14.10		0.313
860205	1150	24640	3 4	1.5								0.350
860303	1050	24997	4	2.0	140.00	NE YET	5.320	11.700		21.20		0.792
860414	1015	24953	8	9.0								0.253
860505	1015	25011	3	12.5	134.50	NE YET	5.440	10.400		10.90		0.065
860612	1035	25051	3	20.0								0.082
860707	1125	25119	3		224.00	NE YET	6.020	17.000		17.20		0.035
860806	1100	25151	3	25.0								0.013
860911	1105	25209	8	20.0	190.50	NE YET	5.430	14.100		15.90		0.022
		MAXIMUM		27.0	294.00		11.40	24.300	0.530	35.50	0.005	0.910
		ARITH MEAN		12.1	192		6.4	14	0.129	14	0.005	0.150<A
		GEOM MEAN		7.2	176		6.1	14	0.108	13		0.072<A
		MINIMUM		0.2	56.000		1.40	4.650	0.030	4.000	0.008	0.004
		STD DEV (GEOM *)		9.0	42		1.9	3	0.039	5		0.192<A
# SAMP IN STATISTICS				104	54		54	54	36	53	1	104
% SAMP (EXCLUDED)												

(CONTD)

S.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02 004 5400

LAT: 42 58 19.79 LONG: 079 19 05.45 U T M: 17 0637150.0 4753850.0 4 - REGION: 02 DISTANCE: 55.555

**INTERIM TEST-NAME: SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	NNOTFR NO2+NO3N FIL.REAC MG/L AS N	NNO2FR NO2-N FIL.REAC MG/L AS N	NNO3FR NO3-N FIL.REAC MG/L AS N	NNTKUR KJDAHL N TOTAL FIL.TOT. MG/L AS N	PBUT LEAD UNF.TOT. MG/L AS PB	PH PH	PHNOL PHENOLS UNF-REAC UG/L PHENOL	PPO4FR PO4 FIL.REAC MG/L AS P	PPUT PHOSPHOR UNF.TOT. MG/L AS P	RSF RESIDUE FILTERED MG/L
780202	1050	38339		0.027	0.930	1.170		6.48	1.000<	0.072	0.118	299.00
780301	1200	38387		0.024	1.220	1.140		7.31	1.000<	0.055	0.125	359.00
780322	1555	38427		0.045	0.770	1.580		7.04	1.000<	0.135	0.226	90.000
780420	1040	38467		0.053	1.13	1.28		7.63	1 <	0.110	0.258	231
780525	1005	38509		0.016	0.210	1.370		8.07	1.000<	0.035	0.150	359.00
780619	0950	38549		0.155	0.615	1.450		7.94	1.000<	0.125	0.245	352.00
780710	1140	38591		0.030	0.590	1.140		6.00	1.000<	0.092	0.154	344.00
780828	1035	38634		0.004	0.005<	1.200		8.05	1.000<	0.056	0.140	453.00
780911	1340	38675		0.002	0.005	0.450		8.17	1.000<	0.054	0.136	378.00
781031	1010	38713		0.032	1.07	1.24		7.71	1	0.057	0.150	373
781128	1100	38738		0.037	1.71	1.56		7.34	1 <	0.108	0.234	334
781212	1025	38776		0.050	3.15	1.48		7.49	1 <	0.115	0.222	237
790110	1100	48319		0.050	2.950	1.320		7.13	1.000<	0.110	0.162	176.000
790226	1210	48363		0.052	1.050	1.760		6.92	4.000	0.102	0.272	104.000
790308	1059	48403		0.034	0.812	1.120		7.42	1.000<	0.081	0.190	91.000
790418	1130	48466		0.058	1.500	1.400		7.62	1.000<	0.094	0.285	161.000
790509	1005	48530		0.013	0.011	1.480		8.20	1.000<	0.016	0.190	263.000
790620	1120	48569		0.020	0.040	1.47		8.12	1 <	0.050	0.230	273
790718	1135	48619		0.018	0.057	1.100		7.92	1.000<	0.075	0.195	257.000
790827	1102	48649		0.037	0.383	0.970		7.89	1.000<	0.020	0.057	215.000
790917	1035	48682		0.105	5.690	1.700		7.75	1.000<	0.130	0.230	345.00
791015	1140	48751		0.043	4.080	1.500		7.63	1.000<	0.035	0.233	412.00
791122	1025	48792		0.041	2.550	1.660		7.74	1.000<	0.072	0.140	358.00
791227	1135	48854		0.076	3.970	2.000		7.39	1.0 <	0.150	0.450	157
800130	1110	28539		0.056	1.840	1.600		7.28	1.000<	0.114	0.253	237.000
800227	1200	28574		0.029	2.570	1.930		7.57	1.000	0.047	0.228	428.00
800319	1100	28599		0.056	1.790	2.900		7.23	1.000	0.155	0.355	202.000
800415	1110	28455		0.056	1.240	1.900		7.65	1.000<	0.150	0.550	205.000
800506	1200	28503		0.054	1.550	1.480		7.74	1.000<	0.064	0.212	250.000
800609	1100	28551		0.047	0.223	1.450		7.95	1.700	0.100	0.202	280.000
800706	1430	80028		0.170	3.370	2.250		7.83		0.050	0.245	
800707	0205	80029		0.185	2.950	1.680		7.82		0.075	0.183	
800715	1050	28596		0.080	1.920	1.430		7.93	1 <	0.059	0.205	399
800811	1055	28644		0.072	0.473	1.050		7.92	1.000<	0.054	0.155	413.00
800908	1020	28694		0.017	0.033	0.980		8.05	1.000<	0.054	0.148	388.000
801007	1035	28738		0.016	0.169	0.900		7.91	1.000<	0.056	0.202	412.00
801117	1050	28787		0.045	3.050	1.520		7.89	1.000<	0.058	0.154	362.00
801217	1025	28826		0.030	0.275	1.320		7.49	1.000<	0.034	0.245	391.00
810122	1215	38332		0.055	4.150	2.320		7.33	1.000<	0.096	0.198	445.00
810309	1035	38403	2.700	0.039	2.660	1.49		7.59		0.055	0.159	327

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 58 18.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4758850.0 4 REGION: 02 DISTANCE: 55.555

*=INTERIM TEST-NAME:			NNOTFR	NNO2FR	NNO3FR	NNTKUR	PBUT	PH	PHNOL	PPO4FR	PPUT	RSF
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	NO2+NO3N FIL.REAC MG/L AS N	NO2-N FIL.REAC MG/L AS N	NO3-N FIL.REAC MG/L AS N	K-DAHL N TOTAL FIL.TOT. MG/L AS N	LEAD UNF.TOT. MG/L AS PB	PH	PHENOLS UNF-REAC UG/L PHENOL	PO4 FIL.REAC MG/L AS P	PHOSPHOR UNF.TOT. MG/L AS P	RESIDUE FILTERED MG/L
810423	1105	33430	0.790	0.052	0.730	1.44		7.90		0.030	0.145	383
810513	1005	38521	1.450	0.036	1.410	1.91		7.70		0.079	0.235	295
810611	1000	38565	0.695	0.026	0.660	1.45		7.89			0.228	327
810728	1035	38603	4.400	0.015	4.390	1.40		7.63		0.035	0.192	405
810825	1505	38675	0.225	0.003	0.220	0.78		8.01			0.025	395
810924	1200	38707	2.550	0.050	2.500	1.45		7.63		0.145	0.252	319
811008	1115	38754	2.800	0.015	2.730	1.48		7.84		0.031	0.175	
811130	1000	38837	4.500	0.080	4.420	1.32		7.63		0.140	0.330	353
820121	1205	43341	2.550	0.078	2.470	1.40		7.09		0.130	0.315	203
820204	1140	48358	2.400	0.086	2.310	1.50		7.43		0.110	0.270	419
820311	1025	48436	0.240	0.002	0.240	0.24		8.33		0.004	0.010	173.0
820415	0955	48493	1.850	0.0130	1.835	1.25		7.45		0.0700	0.207	231.0
820513	1005	48571	0.690	0.0080	0.680	1.20		7.70		0.0420	0.160	300.0
820622	1105	48614	5.500	0.0170	5.480	1.78		7.64		0.0970	0.218	355.0
820706	1205	48659	1.950	0.0130	1.940	1.23		8.13		0.0420	0.220	365.0
820809	1115	43712	0.735	0.0100	0.725	0.75		7.83				327.0
820902	1045	49801	0.340	0.0060	0.334	0.37		8.20		0.0570	0.128	347.0
821005	1355	49842	0.665	0.0035	0.662	0.90		8.17		0.1900	0.273	383.0
821104	1325	48902	2.600	0.0290	2.570	1.050		7.55		0.0550	0.222	403.0
821209	1020	48956	1.850	0.0550	1.790	1.700		7.33		0.1400	0.340	243.0
830105	0950	26511	1.850	0.1600	1.69	1.500		7.37		0.1570	0.370	445.0
830210	1040	23558	2.500	0.0800	2.420	0.200		6.95				335.0
830308	1050	23615	2.250	0.0255	2.220	1.120		7.43		0.0610	0.137	325.0
830406	1030	25660	1.790	0.0355	1.750	1.200		7.40		0.0380	0.230	302.0
830502	1010	23723	1.470	0.0260	1.450	1.620		7.81		0.1370	0.375	304.0
830616	1025	23773	1.250	0.0170	1.230	1.300		7.53		0.1000		250.0
830704	1235	23818	5.900	0.0305	5.870	5.000		7.43		0.1510	0.295	407.0
830810	1015	28863	1.800	0.0305	1.770	1.330		7.43		0.1220	0.243	205.0
830901	1055	28908	0.225	0.0230	0.202	1.380		7.73		0.1750	0.275	245.0
831102	1140	28758	2.500	0.0335	2.470	1.390		8.03		0.0480	0.118	324.0
831205	0950	28804	2.450	0.0890	2.360	1.300		7.62		0.1550	0.390	319.0
840104	1025	64711	1.900	0.0500	1.850	1.530		7.75		0.1420	0.235	326.0
840202	1235	64760	1.490	0.0635	1.430	1.690		7.42			0.164	389.0
840306	1040	64801	1.450	0.0390	1.410	1.260		7.53		0.0790	0.144	266.0
840409	1035	64860	1.300	0.1450	1.150	1.500		7.55		0.1550	0.350	158.0
840507	1050	64922	0.315	0.0320	0.283	1.400		7.82		0.0780	0.173	368.0
840604	1025	65053	0.400	0.0370		1.510		8.25		0.0720	0.213	305.0
840703	1020	65113	2.390	0.1190		1.740	0.004	7.67	0.2 <T	0.1500	0.275	235.3
840813	1030	65177	0.780	0.0560		1.200		7.64		0.1380	0.253	344.0
840912	1255	65207	0.705	0.0835		1.480		7.79		0.1750	0.225	338.0

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 54 18.79 LONG: 079 14 05.45 U T M: 17 0537150.0 4753850.0 4 REGION: 02 DISTANCE: 55.555

*=INTERIM TEST-NAME: SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	NNOTFR NO2+NO3N FIL.REAC MG/L AS N	NNO2FR NO2-N FIL.REAC MG/L AS N	NNO3FR NO3-N FIL.REAC MG/L AS N	NNTKUR KJDAHL N TOTAL FIL.TOT. MG/L AS N	PBUT LEAD UNF.TOT. MG/L AS PB	PH PH	PHNOL PHENOLS UNF-REAC UG/L PHENOL	PPO4FR PO4 FIL.REAC MG/L AS P	PPUT PHOSPHOR UNF.TOT. MG/L AS P	RSF RESIDUE FILTERED MG/L	
841010	1345	65252	0.885	0.0385		1.520		7.91		0.0795	0.190	572.0	
841108	1050	65305	1.000	0.0400		1.070		7.84		0.0785	0.155	560.0	
841203	1105	65352	3.340	0.0500		1.770		7.75		0.1090	0.195	592.0	
850102	1015	34717	4.420	0.0990		1.950		7.49		0.2480	0.598	202.8	
850204	1045	34761	2.150	0.0310		1.480		7.39		0.0355	0.155	445.0	
850306	1040	34808	1.970	0.0395		1.550		7.35		0.1050	0.225	201.5	
850401	1135	34852	2.690	0.1470		3.000		7.54		0.2500	0.810	334.0	
850506	1115	34930	1.150	0.0755		1.250		8.00		0.1010	0.225	288.0	
850605	1340	34930	3.500	0.2060		1.700		7.95		0.1300	0.240	394.0	
850716	1125	35073	1.510	0.0900				8.12		0.0715	0.175	580.0	
850820	1135	35097	0.055	0.0175		0.740		8.27		0.0525	0.115	510.0	
850911	1055	34805	0.105	0.0160		0.900		8.07		0.0515	0.121	562.0	
851009	1050	34850	0.015<T	0.0105		0.590		8.07		0.0355	0.067	516.0	
851112	1200	34912	2.200	0.0560		1.540	0.005<	7.82	1.2	0.195	0.318	195.3	CRO
851204	1250	34949	1.630	0.0740		1.450		7.69		0.1500	0.325	200.2	CRO
860106	1050	24713	1.420	0.0315		1.390		7.64		0.0395	0.148	370.0	
860205	1150	24840	1.630	0.0490		2.120		7.23		0.1550	0.250	224.3	CRO
860303	1050	24997	1.900	0.0350		2.100		7.63		0.0720	0.150	230.0	
860414	1015	24953	2.150	0.0570		1.900		7.91		0.0955	0.242	333.0	
860505	1015	25011	1.250	0.0765		1.550		7.95		0.1130	0.338	303.0	<=>
860612	1035	25051	2.040	0.2130		2.150		7.81		0.2030	0.445	366.0	<=>
860707	1125	25119	0.900	0.0355		1.400		6.07		0.1210	0.220	457.0	<=>
860806	1100	25151	0.745	0.1180		1.090		8.53		0.0915	0.153	411.0	
860911	1105	25209	0.355	0.0485		0.925		8.32		0.0545	0.122	NO DATA	LC
		MAXIMUM	5.900	0.2130	5.870	8.000	0.004	8.58	4.000	0.2500	0.810	562.0	
		ARITH MEAN	1.772<A	0.053	1.74	1.50	0.004	7.72	1 <A	0.100	0.225	316	
		GEOM MEAN	1.232<A	0.038		1.37		7.71		0.034	0.204	301	
		MINIMUM	0.015	0.002	0.005	0.200	0.004	6.48	0.2	0.004	0.010	90.000	
		STD DEV (GEOM *)	1.264<A	0.044		0.78		0.34		0.050	0.105	91	
		# SAMP IN STATISTICS	65	104	75	105	1	104	7	99	101	100	
		% SAMP (EXCLUDED)			1		50		42				

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02 004 5400

LAT: 42 59 18.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4753850.0 4 REGION: 02 DISTANCE: 56.555

**INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	RSP RESIDUE PARTIC. MG/L	RST RESIDUE TOTAL MG/L	SIO3UR SILICATE UNF.REAC MG/L AS SI	SO4UR SULPHATE UNF.REAC MG/L AS SO4	TCMF COLIFORM TOTAL MF CNT /100ML	TCMFBK COLIFORM TOTAL MF BCKGRD CNT /100ML	TURB TURBIDITY FTU	ZNUT ZINC UNF.TOT. MG/L AS ZN
780202	1050	33339	7.10	396.00	2.700	29.000	4700		24.00	
780301	1200	33337	7.70	357.00	3.000	93.000	400		19.00	
780322	1555	38427	48.00	138.00	1.350	17.500	3000		100.00	
780420	1040	38467	78	309	1.50	69	500		140	
780525	1005	38509	41.00	400.00	0.400	108.000	150		26.00	
780619	0950	38549	52.00	434.00	1.250	88.000	800		91.00	
780710	1140	38571	40.00	334.00	0.350	83.000	500		61.00	
780828	1035	38654	39.00	442.00	0.600	123.000	2400		25.00	
780911	1340	38675	22.00	400.00	0.550	102.000	420		15.00	
781031	1010	38713	28	431	3.85	95	2500		40	
781128	1100	38738	15	349	3.35	91	3700		63	
781212	1025	38776	8.0	245	3.60	75	3700		77	
790110	1100	43319	16.00	192.00		49.000	3100	380000	73.00	
790226	1210	48363	29.00	153.00		26.500	4000AID	220000	64.00	
790308	1059	48403	32.00	123.00		21.500	1000<	2000	67.00	
790418	1130	48456	32.00	193.00		39.000	10900	9000	130.00	
790509	1005	48530	47.00	310.00		64.000	380	1080	42.00	
790620	1120	48569	40	313		57	2000	7000	53	
790718	1135	48619	32.00	239.00		45.500	1000	13000	46.00	
790827	1102	48649	17.00	233.00		32.500	1300	23000	19.00	
790917	1035	48682	14.00	359.00		70.000	16000	170000	42.00	
791015	1140	48751	30.00	442.00		113.000	27000	53000	45.00	
791122	1025	48792	23.00	331.00		110.000	1000AID	4000	33.00	
791227	1135	43854	107.0	254.0		49.0	5700	21000	200	
800130	1110	28339	10.00	248.00		83.000	500AID	4000	145.00	
800227	1200	28374	21.00	449.00		109.000	12200C	100000	29.00	
800319	1100	28399	42.00	244.00		52.000	4200C	51000	62.00	
800415	1110	28455	172.00	377.00		52.500	20000	110000	190.00	
800506	1200	28503	17.00	257.00		74.000	900AID	3100	67.00	
800609	1100	28581	46.00	326.00		70.500	35000	140000	54.00	
800715	1050	28596	41	440		71.000	1300	8000	65.00	
800811	1055	28644	38.00	451.00		89.500	100AID	14000	55.00	
800908	1020	28674	20.00	308.00		91.500	200AID	10500	21.00	
801007	1055	28738	23.00	435.00		137.000	3600C	52500	30.00	
801117	1050	28787	6.00	368.00		105.000	400AID	2900	43.00	
801217	1025	28826	31.00	422.00		66.000	3000>	3000>	81.00	
810122	1215	33332	15.00	450.00		107.000	2100	11000	61.00	
810309	1035	33403	7						35.00	
810423	1105	33430	31						2.30	
810513	1005	33521	54						33.00	

(CONTD)

S.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-0001-007-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 59 18.79 LONG: 079 19 05.45 U T M: 17 0537150.0 4758850.0 4 REGION: 02 DISTANCE: 55.855

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	RSP RESIDUE PARTIC. MG/L	PST RESIDUE TOTAL MG/L	SI03UR SILICATE UNF.REAC MG/L AS SI	SS04UR SULPHATE UNF.REAC MG/L AS SO4	TCMF COLIFORM TOTAL MF CNT /100ML	TCMFBK COLIFORM TOTAL MF BCKGRD CNT /100ML	TURB TURBIDITY FTU	ZNUT ZINC UNF.TOT. MG/L AS ZN
810611	1000	39565	30						70.00	
810728	1035	39603	45.0						2.70	
810825	1505	39675	15.8						1.17	
810924	1200	39707	43.0						40.00	
811008	1115	39754							31.00	
811130	1000	39837	29.5						129.00	
820121	1205	43341	14.0			66.0			135.00	
820204	1140	43358	26.4			58.0			105.00	
820311	1025	43436	0.900			27.5			1.39	
820415	0955	43493	42.900			59.5			89.00	
820513	1005	43571	48.300			74.7			55.00	
820622	1105	43614	63.300			75.5			91.00	
820706	1205	43659	65.000			69.5			91.00	
820809	1115	43712	24.500			62.3				
820902	1045	43801	26.900			69.6			35.00	
821005	1055	43842	24.000			75.7			23.00	
821104	1025	43902	50.300			110.60	53000<=>	310000	47.00	
821209	1020	43956	46.900			70.20	3700<=>	48000	374.00	
830105	0950	28511	23.330			56.30	1000	20500		
830210	1040	28558	3.540			44.72				
830306	1050	28615	52.300			81.45	1400	6700	73.00	
830406	1030	28630	93.700			58.70			130.00	
830502	1010	28723	95.800			58.10	3900<=>	210000	131.00	
830616	1025	28773	37.200			58.56			365.00	
830704	1235	28818	49.500			64.45	800<=>	21000	490.00	
830810	1015	28853	64.300			55.27				
830901	1055	28908	31.500			59.05	400<=>	27000	59.00	
831102	1140	28758	21.900				1000	4200	23.00	
831205	0950	28804	58.700			75.40			157.00	
840104	1025	64711	22.900			61.36	1000	25000	77.00	
840202	1235	64750	19.100			91.57			23.00	
840306	1040	64801	14.800			67.95	1500	5100		
840409	1035	64860	45.400			33.68			340.00	
840507	1050	64922	53.410			71.45	1700	7500	50.00	
840604	1025	65053	40.350			47.53			76.00	
840703	1020	65113	51.000				1400	13300	117.00	0.014
840813	1030	65177	21.260						63.00	
840912	1255	65207	36.910			62.94	3300<=>	240000>	65.00	
841010	1345	65252	41.810			89.05			57.00	
841108	1050	65305	31.340			76.65	7000<=>	40000	45.00	

(CONTD)

B.C.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE: RIVER

STATION ID: 11-00J1-0J7-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 42 55 15.79 LONG: 079 19 05.45 U T M: 17 0637150.0 4753850.0 4 REGION: 02 DISTANCE: 35.455

*=INTERIM TEST-NAME:		RSP	RST	SIO3UR	SSO4UR	TCMF	TCMFBK	TURB	ZNUT
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	RESIDUE PARTIC. MG/L	RESIDUE TOTAL MG/L	SILICATE UNF.REAC MG/L AS SI	SULPHATE UNF.REAC MG/L AS SO4	COLIFORM TOTAL MF CNT /100ML	COLIFORM TOTAL MF BCKGRD CNT /100ML	TURBIDITY FTU	ZINC UNF.TOT. MG/L AS ZN
841203	1105	65552	31.050					62.00		
850102	1015	34717	78.500		48.79	29000<=>	800000	195.00		
850204	1045	34751	15.210					45.00		
850306	1040	34808	50.050		58.90	35000	7000<=>	19.20		
850401	1135	34862	406.900							
850506	1115	34930	44.720		69.60	300<=>	22000	54.00		
850605	1340	34950	41.050		72.00			73.00		
850716	1125	35073	27.240		75.15	200<=>	140000	75.00		
850820	1135	35097	28.140					54.00		
850911	1055	34805	33.630		143.90	5700<=>	50000	49.00		
851009	1050	34850	27.900					31.00		
851112	1200	34912	51.670			152000>	320000	151.00	0.051	
851204	1250	34949	44.840					186.00		
860106	1050	24713	9.439		73.45	550	940	41.00		
860205	1150	24840	29.250					71.00		
860303	1050	24997	9.745		55.00	3900	16000	31.00		
860414	1015	24953	46.4					106.00		
860505	1015	25011	51.6 <=>		45.35	320<=>	7000	160.00		
860612	1035	25051	67.3 <=>					200.00>		
860707	1125	25119	33.8 <=>		72.90			82.00		
860806	1100	25151	31.0					35.00		
860911	1105	25209	NO DATA|LC		69.95			43.00		
		MAXIMUM	406.900	492.00	5.35	143.90	152000	800000	460.00	0.051
		ARITH MEAN	41	331	1.87	71	9240	70544	81	0.022
		GEOM MEAN	30	314	1.37	66				0.021
		MINIMUM	0.900	123.00	0.350	17.500	100	940	1.17	0.014
		STD DEV (GEOM *)	65	99	1.34	25				0.012
		# SAMP IN STATISTICS	100	37	12	79	58	46	95	2
		% SAMP (EXCLUDED)					3	4	1	

E.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-038-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 05 27.94 LONG: 079 45 06.02 U T M: 17 0600310.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

**INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	SAMPLE DEPTH M	PROJECT SUB-PROJ CODE	ALKT ALK TOTAL MG/L AS CACO3	ALUT ALUMINUM UNF.TOT. MG/L AS AL	ASUT ARSENIC UNF.TOT. MG/L AS AS	BODS BOD 5 DAY TOT.DEM. MG/L AS O	CAUR CALCIUM UNF.REAC MG/L AS CA	CCNAUR CYANIDE AVAIL UNF.REAC MG/L AS HCN	CDUT CADMIUM UNF.TOT. MG/L AS CD	CLIDUR CHLORIDE UNF.REAC MG/L AS CL
790110	1005	43318	0.30	0101		0.340	0.001	0.6		0.010<	0.005 <	33.000
790226	1340	43362	0.30	0101		4.000	0.001	4.0		0.010<	0.005 <	17.500
790308	1007	43402	0.30	0101		5.900	0.001	2.2		0.010<	0.005 <	19.000
790418	1020	43465	0.30	0101		0.890	0.001	1.0		0.010<	0.005 <	24.500
790509	0925	43529	0.30	0101		7.9	0.001 <	1.8		0.01 <	0.005 <	43.500
790620	1015	43558	0.30	0101	143	0.54	0.002	1.0		0.01 <	0.005 <	55
790718	1035	43618	0.30	0101	154	3.900	0.002	1.0		0.010	0.005 <	53.000
790827	1017	43649	0.30	0101	97	1.400	0.001 <	1.4		0.010<	0.030	21.000
790917	0945	43631	0.30	0101	128	2.900	0.002	1.2		0.110	0.005 <	43.000
791015	1005	43750	0.30	0101	131	1.500	0.001 <	1.8		0.010<	0.005 <	24.000
791122	0930	43771	0.30	0101	129	1.100	0.013	0.4		0.010<	0.005 <	30.000
791227	1055	43855	0.30	0101	45	4.500	0.001	1.6				15.0
800130	1010	23338	0.30	0101	106	2.800	0.001 <	0.6		0.010<	0.005 <	31.000
800227	1030	23373	0.30	0101	80.0	5.000	0.002	3.6		0.010<	0.005 <	45.500
800319	0945	23397	0.30	0101	48.0	16.000	0.005	5.6		0.010<	0.005 <	23.500
800415	1000	23453	0.30	0101	57.0	41.000	0.009	2.0		0.010<	0.005 <	13.000
800506	1015	23501	0.30	0101	114.0	3.000	0.002	4.0		0.010<	0.005 <	40.000
800609	0940	23530	0.30	0101	115.0	5.500	0.001	2.2		0.010<	0.005 <	4.450
800706	1310	80032	0.30	0101								
800707	0350	80033	0.30	0101								
800715	1000	23595	0.30	0101		2.50	0.001	1.2		0.01 <	0.005 <	82.500
800811	1005	23643	0.30	0101	150	1.2	0.001 <	1.4		0.01 <	0.0003	37.0
800908	0935	23673	0.30	0101	123.0	1.7	0.001 <	1.2		0.01 <	0.0002	25.500
801007	0940	23737	0.30	0101	123.0	0.950	0.001	1.2		0.010<	0.0002<	30.000
801117	0950	23756	0.30	0101	126.0	0.560	0.0010	1.4		0.010<	0.0002<	31.500
801217	0900	23825	0.30	0101	172.0	5.1	0.001 <	1.0			0.0004	
810122	1305	33331	0.30	0101	203.0	1.000	0.0010<	0.4		0.010<	0.0002<	92.000
810202	0940	33364	0.30	0101	147.0	1.000	0.0010<	3.4			0.0003	97.000
810309	0935	38401	0.30	0101	126			0.6	99.0		0.0002<	65.00
810423	1020	38479	0.30	0101	132			1.6	53.0			73.00
810513	0920	33520	0.30	0101	144			2.8	54.0		0.0002<	49.00
810611	0920	33554	0.30	0101	150			1.2	93.0		0.0001	85.00
810728	0900	33601	0.30	0101	142			2.6	67.0		0.0001<	50.50
810831	0940	33673	0.30	0101	160			3.0	55.2		0.0002<	65.00
810924	0950	33705	0.30	0101	100			1.2	43.2		0.0001<	22.00
811006	0950	38752	0.30	0101	121			1.0	47.0		0.0001<	27.00
811105	0915	33796	0.30	0101	136			1.4 U	70.0		0.0001<	31.00
811217	0940	38881	0.30	0101	125			1.8	52.0		0.0002	25.00
820121	1045	43539	0.30	0101	154				67.0		0.0004	35.00
820311	0910	43454	0.30	0101	244			1.20	110.0		0.0003	90.00

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

**INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	FWSADP SAMPLE DEPTH M	FGPROJ PROJECT SUB-PROJ CODE	ALKT ALK TOTAL MG/L AS CACO3	ALUT ALUMINUM UNF.TOT. MG/L AS AL	ASUT ARSENIC UNF.TOT. MG/L AS AS	BOD5 BOD 5 DAY TOT.DEM. MG/L AS O	CAUR CALCIUM UNF.REAC MG/L AS CA	CNNAUR CYANIDE AVAIL UNF.REAC MG/L AS HCN	CDUT CADMIUM UNF.TOT. MG/L AS CD	CLIDUR CHLORIDE UNF.REAC MG/L AS CL
820415	0850	48491	0.50	0101	92.9			1.4	45.0		0.0002<	29.50
820513	0925	48570	0.50	0101	171.4			1.13	154.0		0.0004	100.00
820622	0905	48612	0.30	0101	102.3			1.91	53.5		0.0007	34.60
820706	1035	48657	0.30	0101	143.2			1.06	64.5		0.0005	39.90
820809	1000	48710	0.30	0101	146.3			1.19	73.7		0.0002<	62.50
820902	0930	48799	0.30	0101	147.4			2.15	73.7		0.0002	53.00
821005	0935	48840	0.30	0101	135.2			1.62	59.4		0.0002	55.00
821104	0915	48900	0.30	0101	84.2			2.85	51.1		0.0006	34.60
821209	0955	48954	0.30	0101	110.7			1.17	57.5		0.0002	29.70
830105	0935	28509	0.30	0101	119.2			1.43	58.8		0.0002<	34.60
830210	0915	28556	0.30	0101	126.4				69.2		0.0002<	36.50
830308	0930	28613	0.30	0101	89.1			1.91	57.9		0.0002<	30.90
830406	0925	28658	0.30	0101	97.5			1.48	53.1		0.0006	26.50
830502	0900	28721	0.30	0101	82.7			2.92	45.7		0.0007	17.60
830616	0925	28771	0.30	0101	149.6			2.75	85.1		0.0002<	48.40
830704	1135	28816	0.30	0101	137.8			1.52	92.3		0.0020	53.20
830810	0910	28861	0.30	0101	155.4			4.85	79.5		0.0002<	39.20
830901	0955	28906	0.30	0101	149.2			1.45	65.5		0.0002	31.40
831004	0920	28951	0.30	0101								
831102	1025	28756	0.30	0101	143.1			1.82	61.5		0.0004	35.92
831205	0840	28802	0.30	0101	133.4			1.19	73.5		0.0002<	35.32
840104	0905	64709	0.30	0101	135.2			1.09	74.40		0.0003	41.34
840202	1125	64758	0.30	0101	159.0			0.73	102.00		0.0002<	74.00
840305	1015	64799	0.30	0101	129.5			1.25	67.40		0.0004	59.00
840409	0905	64858	0.30	0101	82.2			2.33	37.00		0.0002<	27.93
840507	0925	64920	0.30	0101	114.4			1.75	59.50		0.0002<	35.06
840604	0915	65061	0.30	0101	159.0			1.95	71.30		0.0003<	44.27
840703	0910	65111	0.30	0101	141.2			2.75	74.60		0.0002	39.32
840813	0925	65175	0.30	0101	146.1			0.20<T	92.30		0.0003	48.30
840912	1145	65205	0.30	0101	33.8			3.36	59.20		0.0003	29.98
841010	1450	65250	0.30	0101	201.9			1.80	55.40		0.0005	31.72
841108	0930	65303	0.30	0101	121.0			1.33	55.00		0.0002<	33.38
841203	0955	65350	0.30	0101	129.0			0.61	50.10		0.0002<	33.28
850102	0915	34715	0.30	0101	62.2			1.62	41.40		0.0002<	45.36
850204	0940	34759	0.30	0101	190.6			1.73	154.00		0.0002<	88.05
850306	0935	34806	0.30	0101	87.5			1.52	49.10		0.0002<	45.20
850401	1010	34860	0.30	0101	52.4			3.40	32.25		0.0002<	19.35
850506	1010	34928	0.30	0101	134.1			4.41	92.00		0.0003<	51.70
850605	0940	34978		0101	134.1			2.40	95.15		0.0003<	65.95
850716	1015	35071	0.50	0101	136.5			1.70	135.40		0.0006	79.65

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-005-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 46 06.02 U T M: 17 0503300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:		FWSAMP	FGPROJ	SLKT	ALUT	ASUT	BODS	CAUR	CONAUR	COUT	CLIDUR
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	SAMPLE DEPTH M	PROJECT SUB-PROJ CODE	ALK TOTAL MG/L AS CACO3	ALUMINUM UNF.TOT. MG/L AS AL	ARSENIC UNF.TOT. MG/L AS AS	BOD 5 DAY TOT.DEM. MG/L AS O	CALCIUM UNF.REAC MG/L AS CA	CYANIDE AVAIL UNF.REAC MG/L AS MCN	CADMIUM UNF.TOT. MG/L AS CD	CHLORIDE UNF.REAC MG/L AS CL
850820	1030	35095	0.30	0101	141.6			3.05	178.40		0.0005<	110.35
850911	0950	34803	0.30	0101	152.9			0.75	165.30		0.0005<	132.50
851009	0940	34648	0.30	0101	127.7				62.98		0.0002<	40.34
851112	1015	34908	0.30	0101	64.5			6.80<=>	35.10		0.0006	19.00
851204	1105	34947	0.30	0101	96.1			0.57<T	45.30			24.75
860106	0935	24711	0.30	0101	146.1			0.75	92.10		0.0005<	55.50
860205	1035	24838	0.30	0101	62.5			3.70	47.20		0.0005<	40.30
860303	0945	24885	0.30	0101	143.9			1.00	172.30		0.0005<	77.50
860414	0910	24951	0.30	0101				1.9	43.40		0.0005<	40.30
860505	0910	25009	0.30	0101	149.8			2.0	85.30		0.0005<	63.50
860612	0930	25059	0.30	0101	140.8			2.1	89.20		0.0005<	9.30
860707	1010	25117	0.30	0101	140.5			1.7	83.20		0.0005<	56.00
860806	0945	25149	0.30	0101	152.0			1.5 <T	92.70		0.0005<	NO DATA|DI
860911	0950	25207		0101	130.2			NO DATA|TX	56.30		0.0005<	43.70
		MAXIMUM	0.30		244	41.000	0.013	6.80	185.00	0.110	0.030	132.30
		ARITH MEAN	0.30		127	4.3	0.003	1.9 <A	79.3	0.060	0.001	45
		GEOM MEAN			122	2.5		1.6 <A	71.1			39
		MINIMUM	0.30		45	0.54	0.001	0.20	32.25	0.010	0.0001	4.450
		STD DEV (GEOM A)			35	8.1		1.2 <A	33.5			24
		# SAMP IN STATISTICS	92		84	26	17	37	65	2	29	89
		% SAMP (EXCLUDED)					34			91	67	

*=INTERIM TEST-NAME:		COD	COLAP	CONDAM	CONDZS	COUT	CRUT	CUUT	DO	DOC	FCMF
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	CHEM. OX DEMAND MG/L AS O	COLOUR APPARENT HZU	CONDUCT. AMBIENT UMHO/CM AMBIENT	CONDUCT. 25C UMHO/CM AT 25 C	COBALT UNF.TOT. MG/L AS CO	CHROMIUM UNF.TOT. MG/L AS CR	COPPER UNF.TOT. MG/L AS CU	DISOLVED OXYGEN MG/L AS O	CARBON DISOLVED ORGANIC MG/L AS C	FECAL COLIFORM MF CNT /100ML
790110	1305	43318	36	45.000		550.0	0.020 <	0.020 <	0.020	10.5		20AID
790226	1340	48362	45	160.000		195.0	0.020 <	0.020 <	0.010	11.1		100AID
790308	1007	48402	24	145.000		310.0	0.020 <	0.030 <	0.010 <	11.5		100AID
790418	1020	48465	18	215.000		320.0	0.020 <	0.020 <	0.010 <	9.9		10<
790509	0925	48529	14	23.000		740.0	0.02 <	0.02 <	0.01 <	7.0		84
790620	1015	43558	34	92		790	0.02 <	0.03	0.01	4.8		240
790718	1035	48618	22	70.000		810.0	0.020 <	0.020 <	0.020	5.5		440
790827	1017	43648	10	2.000		310.0	0.020 <	0.020 <	0.010 <	4.8		420
790917	0945	48681	34	105.000		570.0	0.020 <	0.020 <	0.010 <	5.6		300
791015	1005	48750	36	44.000		450.0	0.020 <	0.020 <	0.020	9.4		70AID

(C O N T D)

S.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 46 06.02 U T M: 17 0600300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:			COD	COLAP	CONDAM	COND25	COUT	CRUT	CUUT	DO	DOC	FCMF
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	CHEM. OX DEMAND MG/L AS O	COLOUR APPARENT HZU	CONDUCT. AMBIENT UMHO/CM AMBIENT	CONDUCT. 25C UMHO/CM AT 25 C	COBALT UNF.TOT. MG/L AS CO	CHROMIUM UNF.TOT. MG/L AS CR	COPPER UNF.TOT. MG/L AS CU	DISSOLVED OXYGEN MG/L AS O	CARBON DISOLVED ORGANIC MG/L AS C	FECAL COLIFORM MF CNT /100ML
791122	0930	48791	14	35.000		485.0	0.020 <	0.020 <	0.010 <	9.2		100<
791227	1055	48853	20	560		305				10.6		1220
800130	1010	23338	42	66.000		485.0	0.02 <	0.020 <	0.010	10.6		20<
800227	1030	23373	44	70.000		560.0	0.020 <	0.020 <	0.010 <	9.9		140AID
800319	0945	23397	36	70.000>		290.0	0.020 <	0.050	0.020	12.0		4500
800415	1000	23453	58	70.000>		290.0	0.020 <	0.070	0.040	10.7		13500
800506	1015	23501	38	70.000>		550.0	0.020 <	0.020 <	0.020	7.9		24
800609	0940	23580	44	70.000>		750.0	0.020 <	0.030	0.010	7.3		1500
800706	1310	80032				1100.0				8.0		
800707	0050	80033				1100.0				5.6		
800715	1000	28595	42			1150.0	0.02 <	0.02 <	0.01 <	4.7		130
800811	1005	29643	26	70 >		500	0.012	0.033	0.001	6.2		
800908	0935	28693	40	35.000		465.0	0.002 <	0.004	0.004	5.4		730
801007	0940	29737	18	70 >		460.0	0.002 <	0.005	0.003	9.0		300
801117	0950	28736	23	35.000		520.0	0.0005<	0.0010	0.0020	12.1		75
801217	0900	28825	38	70.000>		1100.0	0.0005<	0.005	0.007	10.6		150AID
810122	1305	35331	31	70.000>		1260.0	0.0005<	0.0010<	0.0020	5.0		300
810202	0940	38364	45	70.000>		1140.0	0.0005<	0.0020	0.0050	5.8		240
810309	0935	38401	47.548			960		0.002 <	0.003	11.80	6.8	10<
810423	1020	38479	27			980				10.60	9.1	30<=>
810513	0920	38520	44			960		0.002 <	0.004	9.70	10.4	130
810611	0920	38564	27			1040		0.0090	0.007	4.00	8.4	160
810728	0900	38601	32			700		0.0090	0.005	5.70	7.1	360
810831	0940	38673	20			800		0.0050	0.005	5.10	6.1	960
810924	0950	38705	32			430		0.0060	0.003	6.80	9.3	560
811008	0950	38752	31			520		0.0060	0.013	8.90	9.5	5500
811105	0915	38796	18			560		0.0070	0.010	10.20	9.9	1000
811217	0340	38831	9			430		0.003	0.008	13.60	7.0	10<=>
820121	1045	43339	27			570		0.004	0.008	10.50	7.2	10<
820311	0910	43434				990		0.001 <	0.001	7.30	5.7	70<=>
820415	0850	43491	17			463		0.006	0.007	10.80	5.7	20<=>
820513	0925	43570	29			1260.0		0.010	0.014	7.00	6.2	920
820622	0905	43612	46			513.0		0.200	0.015	10.60	8.4	3100
820706	1035	48657	32			565.0				9.40	6.3	80<=>
820809	1000	46710	20			690.0		0.001 <	0.004	5.80	5.6	260
820902	0930	43799	24			687.0		0.004	0.023	6.30	5.2	330
821005	0935	48840	28.4			766.0		0.006	0.013	6.60	6.1	360
821104	0915	43900	47.9			502.0		0.014	0.024	5.30	9.4	5000>
821209	0355	48954	25.9			503.0		0.005	0.010	10.70	6.9	130<=>
830105	0335	28509	10.2			515.0		0.002	0.010	11.20	5.5	40<=>

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 46 06.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	TEST-NAME: COD CHEM. OX DEMAND MG/L AS O	COLAP COLOUR APPARENT HZU	CONDAM CONDUCT. AMBIENT UMHO/CM AMBIENT	CONDZS CONDUCT. 25C UMHO/CM AT 25 C	COUT COBALT UNF.TOT. MG/L AS CO	CRUT CHROMIUM UNF.TOT. MG/L AS CR	CUJT COPPER UNF.TOT. MG/L AS CU	DO DISOLVED OXYGEN MG/L AS O	DOC CARBON DISOLVED ORGANIC MG/L AS C	FCMF FECAL COLIFORM MF CNT /100ML
830210	0915	28556	15.5			559.0		0.004	0.015	11.20	5.9	
830308	0930	28613	36.4			575.0		0.004	0.007	9.30	7.3	240
830406	0925	28658	49.6			529.0		0.009	0.023	9.30	6.1	
830502	0900	28721	20.7			425.0		0.006	0.013	7.60	9.4	1520
830616	0925	28771	19.4			750.0		0.005	0.015	5.30	6.2	
830704	1135	28816	39.2			327.0		0.010	0.023	7.10	10.0	1000
830810	0910	28861	30.7			525.0		0.005	0.011	6.80	9.2	
830901	0955	28906	55.1			520.0		0.005	0.014	7.30	5.6	500<=>
831004	0920	28951								9.40		
831102	1025	28756	15.5			523.0		0.003	0.015	9.90	6.2	120<=>
831205	0840	28802	18.2			562.0		0.003	0.008	11.30	6.4	
840104	0905	64709	21.3			655.0		0.003	0.008	11.30	6.5	40<=>
840202	1125	64758	24.4			947.0		0.130	0.005	11.80	6.9	
840305	1015	64799	4.9	<T		561.0		0.054 U	0.005	11.50	5.8	20<
840409	0905	64858	25.0			380.0		0.004	0.005	11.60	5.0	
840507	0925	64920	25.4			521.0		0.007	0.007	9.80	6.8	320
840604	0915	65061	112.0		580	544.0		0.008	0.006	5.30	6.0	
840703	0910	65111	30.0		600	637.0		0.004	0.005	6.00	6.4	140<=>
840813	0925	65175	47.0		710	792.0		0.007	0.009	5.00	5.5	
840912	1145	65205	37.0		430	560.0		0.009	0.005	6.90	9.5	5300<=>
841010	1450	65250	32.9		330	490.0		0.006	0.005	7.60	6.0	
841108	0930	65303	18.2		345	530.0		0.003	0.005	9.40	6.5	480
841203	0955	65350	15.2		290	535.0		0.003	0.005	11.20	5.7	
850102	0915	34715	27.1		218	455.0		0.006	0.005	11.40	6.7	9300
850204	0940	34759	20.9		600	1148.0		0.009	0.010	10.00	5.8	
850306	0935	34806	18.0		255	525.0		0.004	0.005	10.50	4.9	300<=>
850401	1010	34860	39.8		155	289.0		0.023	0.019	9.20	8.4	
850506	0940	34928	22.1		575	756.0		0.003	0.005	6.90	4.9	120<=>
850605	0940	34978	24.4		650	802.0		0.003	0.003	6.60	4.8	
850716	1015	35071	19.6		1030	1097.0		0.011	0.010	6.30	5.0	80<=>
850820	1030	35095	28.6			1460.0		0.002	0.001	9.10	5.5	
850911	0950	34803				1580.0		0.001	0.001 <W	9.40	5.8	240
851009	0940	34848	23.7			554.0		0.002	0.002	9.10	4.4	
851112	1015	34908	34.8			350.0		0.009	0.007	11.80	9.5	780
851204	1105	34947	23.0			412.0				11.00	6.8	
860106	0935	24711	20.5			765.0		0.002	0.002	9.00	6.2	20<=>
860205	1035	24838	20.9			517.0		0.002	0.002	10.00	5.3	
860303	0945	24885	19.8			1035.0		0.001	0.002	8.50	6.1	20<
860414	0910	24951	17.3			459.0		0.002	0.003	10.30	5.3	
860505	0910	25009	19.0			320.0		0.004	0.005	9.00	5.2	40<=>

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
0004
5400

LAT: 43 03 27.94 LONG: 079 46 06.02 U T M: 17 0600300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:	COD	COLAP	CONDAM	CONDZ5	COUT	CRUT	CUUT	DO	DOC	FCMF
SAMPLE DATE YYMMDD HOUR LMT / SAMPLE NUMBER	CHEM. OX DEMAND MG/L AS O	COLOUR APPARENT HZU	CONDUCT. AMBIENT UMHO/CM AMBIENT	CONDUCT. 25C UMHO/CM AT 25 C	COBALT UNF.TOT. MG/L AS CO	CHROMIUM UNF.TOT. MG/L AS CR	COPPER UNF.TOT. MG/L AS CU	DISSOLVED OXYGEN MG/L AS O	DISSOLVED ORGANIC CARBON MG/L AS C	FECAL COLIFORM MF CNT /100ML
860612 0930 25059	23.0			761.0		0.005	0.003	6.50	5.1	
860707 1010 25117	23.5			592.0		0.004	0.004	6.30	5.8	500
860806 0945 25149	23.4		650	591.0		0.005	0.003	6.30	5.6	
860911 0950 25207	18.3			473.0		0.003	0.003	7.50	5.0	610
MAXIMUM	112.0	560	1000	1580.0	0.012	0.200	0.040	15.60	10.4	13600
ARITH MEAN	30 <A	105	496	569	0.012	0.01	0.01 <A	8.6	6.6	965
GEOM MEAN	27 <A		444	519				8.5	6.5	
MINIMUM	4.9	2.000	155	195.0	0.012	0.0010	0.001	4.00	4.4	10
STD DEV (GEOM *)	15 <A		226	273				2.3	1.5	
# SAMP IN STATISTICS	89	15	15	93	1	68	77	94	55	61
% SAMP (EXCLUDED)		35			96	21	9			11

*=INTERIM TEST-NAME:	FEUT	FSMF	FWPH	FWSTRC	FWTEMP	HARDT	HGUT	HGUR	MNUT	NIUT
SAMPLE DATE YYMMDD HOUR LMT / SAMPLE NUMBER	IRON UNF.TOT. MG/L AS FE	FECAL STREPCUS MF CNT /100ML	PH FIELD	STREAM COND.	WATER TEMP DEG.C	HARDNESS TOTAL MG/L AS CACO3	MERCURY UNF.TOT. UG/L AS HG	MAGNESIM FIL.REAC MG/L AS MG	MANGANSE UNF.TOT. MG/L AS MN	NICKEL UNF.TOT. MG/L AS NI
790110 1005 43318	0.900	130		4	0.5		0.020<		0.099	0.020 <
790226 1340 43362	3.700	6500		3	2.5		0.020<		0.118	0.020 <
790308 1007 43402	3.900	1200		3	0.8		0.020<		0.250	0.020 <
790418 1020 46465	2.900	100AID		3	9.2		0.020<		0.104	0.020 <
790509 0925 43529	3.000	4		5	19.0		0.02 <		0.310	0.02 <
790620 1015 43558	5.1	300		5	19.2		0.02 <		0.70	0.02 <
790718 1035 43618	3.500	80AID		5	22.0		0.020<		0.590	0.040
790827 1017 43646	0.700	700		6	19.5		0.030<		0.023	0.020
790917 0945 43681	2.300	560		6	15.0		0.020<		0.157	0.020 <
791015 1005 43750	2.100	120		6	8.4		0.020<		0.220	0.020 <
791122 0930 43791	1.000	1500		6	9.0		0.020<		0.090	0.010 <
791227 1055 43853	2.500	3000>		3	2.0				0.172	0.020 <
800130 1010 23338	2.800	100<		4	1.2		0.030<		0.130	0.020 <
800227 1030 23373	4.300	1640		4	1.0		0.020<		0.400	0.020 <
800319 0945 23397	14.000	8400		3	2.5		0.030		0.280	0.020 <
800415 1000 23453	48.000	15000>		3	5.0		0.030		0.530	0.020 <
800506 1015 23501	4.200	12		3	17.0		0.030<		0.320	0.020 <
800609 0940 23530	7.200	1500>		6	14.0		0.040		0.410	0.020 <
800706 1310 80032				8	24.5					
800707 0950 80033				8	22.0					

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 05 27.94 LONG: 079 46 06.02 U T M: 17 0600300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	FEUT IRON UNF.TOT. MG/L AS FE	FSMF FECAL STREPCUS MF CNT /100ML	FWPH PH FIELD	FWSTRC STREAM COND.	FWTEMP WATER TEMP DEG.C	HARDT HARDNESS TOTAL MG/L AS CACO3	HGUT MERCURY UNF.TOT. UG/L AS HG	MGUR MAGNESIUM FIL.REAC MG/L AS MG	MNUT MANGANESE UNF.TOT. MG/L AS MN	NIUT NICKEL UNF.TOT. MG/L AS NI
800715	1000	28595	2.200	640	7.4	5	24.0		0.030<			0.02 <
800811	1005	28643	4.2		7.6	5	21.5		0.04		0.327	0.005
800908	0935	28693	2.500	320	6.5	5	19.5		0.04 <		0.134	0.004
801007	0940	28737	1.500	760	7.1	5	7.0		0.020<		0.110	0.006
801117	0950	28756	0.8400	104	7.5	5	4.0		0.030		0.076	0.003 <
801217	0900	28825	6.9000	50<	7.35	4	0.3		0.05		0.620	0.005
810122	1305	33331	1.3000	20AID	7.1	4	1.0		0.050<		0.530	0.003 <
810202	0940	33364	1.4000	390	6.9	4	2.0		0.050<		0.600	0.003 <
810309	0935	33401		10<	7.30	3 5	5.8	355		35.00		0.002 <
810423	1020	33479		150	7.75	3 5	9.00	357		37.50		
810513	0920	33520		110	7.35	5	10.0	358		35.00		0.005
810611	0920	33554		220	7.30	5	16.0	393		39.00		0.0005<
810728	0900	33601		1080		5	17.5	258		22.00		0.0070
810831	0940	33673		1320	7.60	5 7	21.0	316		25.00		0.0030
810924	0950	33705		2300	7.30	5	10.8	159		15.00		0.0050
811008	0950	33752		7600	7.90	3	7.5	196		19.00		0.0050
811105	0915	33796		800<=>		5	4.0	257		20.00		0.0060
811217	0940	33851		50<=>	8.20	8	0.5	177		11.50		0.004
820121	1045	43339		10<	7.10	4	3.0	233		15.00		0.004
820311	0910	43434		170	6.50	4	3.0	336		27.00		0.001
820415	0850	43491		580	7.10	3	5.0	176.0		14.30		0.004
820513	0925	43570		270	7.30	8	13.0	564.0		43.70		0.006
820622	0905	43612		7400	7.50	3	15.0	201.0		15.30		0.110
820706	1035	43657			8.00	3	22.0	225.0		15.30		0.009
820809	1000	43710		240	7.30	3	22.0	273.0		15.50		0.003
820902	0930	43799		680	7.55	3	18.0	263.0		14.20		0.004
821005	0935	43840		380	7.65	3	13.0	320.0		23.50		0.004
821104	0915	43900		3000>	7.10	3 4	11.0	198.0		17.00		0.007
821209	0855	43954		320	7.90	3	2.0	211.0		15.20		0.004
830105	0835	28509		20<=>	7.85	4	1.0	206.0		14.40		0.002
830210	0915	28556			8.00	4	0.5	244.0		17.40		0.005
830308	0930	28613		1600	7.75	3	9.0	241.0		23.50		0.006
830406	0925	28658			7.90	3	7.5	234.0		21.50		0.009
830502	0900	28721		3500	7.70	3	11.5	152.0		15.50		0.011
830616	0925	28771			7.70	3	22.5	318.0		23.00		0.005
830704	1135	28816		800<=>	7.60	3	26.5	344.0		27.50		0.012
830810	0910	28851			7.70	3	20.0	258.0		21.30		0.006
830901	0955	28906		300<=>	7.75	3	21.0	231.0		15.70		0.006
831004	0920	28951			7.70	3	14.0					
831102	1025	29756		20<	7.60	3	10.0	215.0		15.00		0.005

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	**INTERIM TEST-NAME: FEUT IRON UNF.TOT. MG/L AS FE	FSMF FECAL STREPCOCCUS MF CNT /100ML	FWPH PH FIELD	FWSTRC STREAM COND.	FWTEMP WATER TEMP DEG.C	HARDT HARDNESS TOTAL MG/L AS CACO3	HGUT MERCURY UNF.TOT. UG/L AS HG	MGUR MAGNESIUM FIL.REAC MG/L AS MG	MNUT MANGANESE UNF.TOT. MG/L AS MN	NIUT NICKEL UNF.TOT. MG/L AS NI
831205	0840	29802			7.60	3	3.0	274.0		21.70		
840104	0905	64709		20<	7.40	4	2.5	252.0		18.40		0.002
840202	1125	64758			7.75	4	1.0	375.0		29.20		0.003
840305	1015	64799		40<=>	7.00	4	1.0	242.0		17.30		0.002
840409	0905	64858			7.80	3	5.0	134.0		10.20		0.003
840507	0925	64920		100<=>		3	13.5	231.0		20.00		0.004
840604	0915	65061			7.70	3	18.0	266.0		21.00		0.006
840703	0910	65111		1300	7.95	3	22.0	259.0		20.00		0.008
840813	0925	65175			7.95	3	22.5	320.0		21.40		0.007
840912	1145	65205		5400	7.70	3	17.5	217.0		15.30		0.005
841010	1450	65250			7.60	8	15.0	192.0		63.10		0.007
841108	0930	65303		1240	8.10	8	5.5	195.0		13.90		0.008
841203	0955	65350			8.30	3	3.0	211.0		14.30		0.002
850102	0915	34715		5750	7.90	3	2.0	156.0		12.90		0.002
850204	0940	34759			8.00	4	1.0	553.0		41.00		0.005
850306	0935	34806		600<=>	8.00	4	1.5	136.0		15.40		0.002
850401	1010	34850			7.90	3	4.5	131.0		12.13		0.002
850506	1010	34928		260	8.30	3	14.0	323.0		22.68		0.016
850605	0940	34978			8.10	3	13.0	332.0		22.99		0.002 <
850716	1015	35071		140<=>	7.70	3	20.5	432.0		34.30		0.005
850820	1030	35095			7.70	3	19.5	647.00		43.900		0.003
850911	0950	34803		700	7.75	8	15.0	667.50		49.700		0.003
851009	0940	34848			7.75	3	13.5	212		13.23		0.002
851112	1015	34905		740	7.60	3	4.5	149.50		13.200		0.004
851204	1105	34947			8.30	3 4	1.0	170.50		13.000		0.008
860106	0935	24711		20<	7.95	4	1.0	330.00		24.300		
860205	1035	24838			7.70	3 4	2.0	134.00		15.100		0.003
860303	0945	24835		20<	8.15	4	2.0	564.00		32.800		0.002
860414	0910	24951			7.95	3	3.0	156.00		11.500		0.002
860505	0910	25009		20<	7.90	3	11.0	315.50		24.000		0.002
860612	0930	25059			7.90	3	18.5	322.00		24.100		0.004
860707	1010	25117		90<=>	8.00	3		287.50		19.400		0.005
860806	0945	25149			7.80	3	21.5	290.00		20.300		0.004
860911	0950	25207		560		3	18.5	193.50		12.700		0.005
		MAXIMUM	48.000	8400	8.30		26.5	657.50	0.050	63.10	0.70	0.044
		ARITH MEAN	5.1	1293	7.7		10.7	251	0.04	22.42	0.29	0.110
		GEOM MEAN	2.9		7.6		5.6	251		20.51	0.22	0.005
		MINIMUM	0.700	4	6.5		3.5	131.0	0.030	10.20	0.025	0.001
		STD DEV (GEOM +)	9.2		0.4		5.0	118		10.35	0.21	
		# SAMP IN STATISTICS	25	55	70		95	55	5	55	25	56
		% SAMP (EXCLUDED)		19					76			25

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-005-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0503300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	NNHTER NH3-N TOTAL FIL.REAC MG/L AS N	NNOTER NO2+NO3N FIL.REAC MG/L AS N	NNO2FR NO2-N FIL.REAC MG/L AS N	NNO3FR NO3-N FIL.REAC MG/L AS N	NNTKUR KJDAHL N TOTAL FIL.TOT. MG/L AS N	PBUT LEAD UNF.TOT. MG/L AS PB	PH PH	PHNOL PHENOLS UNF-REAC UG/L PHENOL	PPO4FR PO4 FIL.REAC MG/L AS P	PPUT PHOSPHOR UNF.TOT. MG/L AS P
790110	1005	48318	0.260		0.020	1.990	1.040	0.030<	7.59	1.000<	0.011	0.050
790226	1340	48562	0.424		0.036	1.200	1.640	0.030<	6.94	2.000	0.087	0.250
790308	1007	48402	0.136		0.039	1.760	1.160	0.030<	7.27	1.000<	0.041	0.145
790418	1020	45405	0.156		0.036	1.640	0.930	0.030<	7.52	1.000	0.030	0.123
790509	0925	45529	0.044		0.009	0.259	0.950	0.03 <	7.36	1.000<	0.005	0.150
790620	1015	48558	0.082		0.016	0.109	0.92	0.04 <	7.91	1 <	0.022	0.210
790718	1035	48618	0.014		0.003	0.007	0.780	0.030<	7.74	1.000<	0.033	0.163
790827	1017	48648	0.024		0.009	0.136	0.290	0.030<	8.13	1.000<	0.005	0.025
790917	0945	48681	0.006		0.010	0.443	0.900	0.030<	7.52	1.000<	0.004	0.133
791015	1005	48750	0.014		0.074	0.224	0.700	0.030<	7.40	1.000<	0.019	0.080
791122	0930	48791	0.028		0.018	0.512	0.690	0.030<	7.87	1.000<	0.013	0.055
791227	1055	48853	0.094		0.082	6.770	1.650		7.36	1.0 <	0.140	0.385
800130	1010	25338	0.108		0.034	2.970	0.910	0.030<	7.53	1.000<	0.026	0.105
800227	1030	25373	0.430		0.044	2.300	2.230	0.030<	7.23	1.000	0.060	0.240
800319	0945	28597	0.640		0.091	2.760	3.100	0.030<	7.24	1.000	0.130	0.560
800415	1000	25453	0.140		0.160	1.990	2.900	0.030<	7.41	1.000<	0.180	0.825
800506	1015	25501	0.122		0.020	0.900	1.550	0.030<	8.02	1.000<	0.009	0.212
800609	0940	25530	0.112		0.160	3.590	1.450	0.030<	7.57	2.000	0.033	0.210
800706	1310	80032	0.038		0.007	0.017	0.760		7.96		0.021	0.112
800707	0350	80033	0.073		0.009	0.016	0.800		7.91		0.021	0.133
800715	1000	25595	0.026		0.004	0.006	0.800	0.03 <	7.71	1 <	0.019	0.125
800811	1005	25643	0.036		0.015	0.189	0.850	0.003<	7.73	1 <	0.033	0.165
800908	0935	25693	0.022		0.012	0.453	0.720	0.003	7.57	2.000	0.036	0.142
801007	0940	28737	0.042		0.006	0.244	0.630	0.003<	7.81	1.000<	0.013	0.145
801117	0950	28756	0.020		0.005	0.345	0.600	0.003<	7.94	1.000<	0.007	0.040
801217	0900	28825	0.094		0.074	8.580	1.530	0.006	7.87	1.000<	0.021	0.212
810122	1305	33331	0.196		0.028	0.698	0.800	0.003	7.41	1.000<	0.012	0.033
810202	0940	33334	0.570		0.049	1.900	1.650	0.003<	7.29	1.000<	0.044	0.150
810309	0935	38401	0.054	3.550	0.027	3.520	0.75	0.003<	7.68	1 <T	0.021	0.064
810423	1020	38479	0.054	0.165	0.010	0.155	0.89		7.78	1 <T	0.010	0.080
810513	0920	38520	0.030	0.550	0.009	0.540	1.14	0.003<	7.35	1 <T	0.011	0.135
810611	0920	38564	0.008	0.425	0.003	0.420	0.88	0.003<	7.98	1 <T	0.035	0.174
810728	0900	38601	0.008	0.600	0.004	0.595	1.06	0.003<	7.76	1 <T	0.040	0.252
810831	0940	38673	0.006	0.465	0.005	0.460	1.05	0.003<	7.50	1 <T	0.061	0.225
810924	0950	38705	0.010	1.900	0.015	1.380	1.25	0.003<	7.76	1 <T	0.100	0.255
811008	0950	38752	0.015	1.100	0.010	1.090	1.15	0.003<	7.59	1 <T	0.068	0.192
811105	0915	38796	0.006	0.590	0.002	0.590	0.70	0.003<	8.04	1 <T	0.024	0.082
811217	0840	38851	0.006	0.695	0.003	0.690	0.62	0.003<	8.06	1 <T	0.013	0.054
820121	1045	48339	0.125	0.725	0.025	0.695	0.82	0.009	7.88		0.015	0.055
820311	0910	48434	0.320	3.550			0.85	0.005	8.30		0.0430	0.085

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	NNHTER NH3-N TOTAL FIL.REAC MG/L AS N	NNOTER NO2+NO3N FIL.REAC MG/L AS N	NNO2ER NO2-N FIL.REAC MG/L AS N	NNO3ER NO3-N FIL.REAC MG/L AS N	NNTKUR KJDAHL N TOTAL FIL.TOT. MG/L AS N	PBUT LEAD UNF.TOT. MG/L AS PB	PH PH	PHNOL PHENOLS UNF-REAC UG/L PHENOL	PPO4FR PO4 FIL.REAC MG/L AS P	PPUT PHOSPHOR UNF.TOT. MG/L AS P
820415	0950	48491	0.010	1.550	0.0110	1.540	0.85	0.003<	7.55	1.0 <T	0.0360	0.205
820513	0925	43570	0.006<T	0.250	0.0030	0.245	0.75	0.003<	7.50	0.2 <W	0.0370	0.165
820622	0905	49612	0.016	3.950	0.0350	3.915	1.65	0.003<	7.72	2.2	0.0940	0.460
820706	1035	49657	0.006	0.720	0.0040	0.715	0.95		7.51	0.2 <T	0.0395	0.265
820809	1000	48710	0.006	0.300	0.0070	0.295	0.68	0.003<	7.90	0.2 <T	0.0390	0.150
820902	0930	49799	0.010	0.235	0.0040	0.228	0.85	0.003	8.16	0.4 <T	0.0500	0.195
821005	0935	48840	0.006	1.050	0.0035	1.050	0.75	0.003	7.95	0.2 <W	0.0370	0.120
821104	0915	49900	0.006	3.550	0.0330	3.520	1.250	0.010	8.00	0.5 <T	0.1150	0.500
821209	0955	49954	0.005	1.450	0.0210	1.430	0.800	0.007	7.56	0.5 <T	0.0450	0.137
830105	0935	23509	0.006	1.550	0.0140	1.540	0.650	0.009	8.00	0.4 <T	0.0260	0.075
830210	0915	23556	0.008	1.500	0.0190	1.480	0.210	0.004	8.15	0.2 <W	0.013	0.075
830308	0930	28615	0.004<T	2.300	0.0270	2.770	0.435	0.040	7.59	0.2 <T	0.0355	0.082
830406	0925	29658	0.008	1.380	0.0070	1.370	0.900	0.005<	8.26	0.5 <T	0.0360	0.155
830502	0900	28721	0.014U	3.310	0.0375	3.270	4.000	0.005	7.57		0.0850	0.470
830616	0925	28771	0.032	0.630	0.0155	0.615	0.900	0.005<	7.77	0.5 <T	0.0500	0.190
830704	1135	28816	0.016	5.620	0.0755	5.540	6.500	0.043	7.70	1.0	0.0300	0.180
830810	0910	28861	0.006	0.415	0.0050	0.409	0.950	0.004	8.10	0.3	0.0460	0.175
830901	0955	29906	0.012	0.445	0.0220	0.423	0.770	0.005<	7.99	-0.2 <T	0.0325	0.165
831004	0920	29951								0.4 <T		
831102	1025	29756	0.050	0.115	0.0060	0.109	0.730	0.007	7.96	0.5 <T	0.0150	0.075
831205	0840	28802	0.054	1.230	0.0225	1.210	0.890	0.005<	7.95	0.2 <W	0.0240	0.085
840104	0905	64709	0.270	1.050	0.0300	1.020	1.050	0.005	8.14	-0.2 <T	0.0340	0.090
840202	1125	64758	0.354	1.400	0.0575	1.340	1.170	0.005<	7.55	-0.4 <T	0.0215	0.087
840305	1015	64799	0.430	2.140	0.0340	2.110	1.290	0.005<	7.50	0.2 <W	0.0320	0.096
840409	0905	64858	0.100	1.300	0.0320	1.270	0.850	0.005<	7.59	-0.4 <T	0.0330	0.145
840507	0925	64920	0.058	1.200	0.0450	1.155	1.150	0.005<	7.72	0.2 <W	0.0440	0.155
840604	0915	65061	0.036	0.450	0.0295		1.030	0.007	8.15	0.2 <W	0.0340	0.275
840703	0910	65111	0.096	0.600	0.0305		1.050	0.006	7.96	-0.5 <T	0.0475	0.210
840813	0925	65175	0.036	0.170	0.0255		0.740	0.005	7.58	-0.4 <T	0.0550	0.175
840912	1145	65205	0.200	10.300	0.2290		2.350	0.007	7.52	0.2 <T	0.2430	0.445
841010	1450	65250	0.032	0.300	0.0350		0.850	0.005<	7.98	0.2 <W	0.0510	0.175
841108	0930	65303	0.056	1.200	0.0330		0.920	0.005<	7.85	0.5 <T	0.0345	0.097
841203	0955	65350	0.058	0.525	0.0175		0.610	0.005<	8.00	0.5 <T	0.0100	0.045
850102	0915	34715	0.054	4.250	0.0600		1.320	0.004	7.57	1.0	0.1350	0.270
850204	0940	34759	0.116	1.730	0.0260		0.850	0.004	7.54	1.0	0.0120	0.070
850306	0935	34806	0.164	2.100	0.0350		0.940	0.005<	7.47	1.5	0.0490	0.117
850401	1010	34860	0.172	5.500	0.1600		2.700	0.011	7.59	1.0	0.1900	0.950
850506	1010	34928	0.554	0.015<T	0.0100		1.500	0.008	7.71	1.0	0.0455	0.190
850605	0940	34978	0.042	0.515	0.0255		0.820	0.005<	8.04	0.5 <T	0.0210	0.164
850716	1015	35071	0.072	0.055	0.0175		0.720	0.004	7.99	0.4 <T	0.0225	0.125

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02 004 5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	NNWTER NH3-N TOTAL FIL.REAC MG/L AS N	NNOTER NO2+NO3N FIL.REAC MG/L AS N	NNO2ER NO2-N FIL.REAC MG/L AS N	NNO3ER NO3-N FIL.REAC MG/L AS N	NNTKUR KJDAHL N TOTAL FIL.TOT. MG/L AS N	PBUT LEAD UNF.TOT. MG/L AS PB	PH PH	PHNOL PHENOLS UNF-REAC UG/L PHENOL	PPO4FR PO4 FIL.REAC MG/L AS P	PPUT PHOSPHOR UNF.TOT. MG/L AS P
850820	1030	35095	0.014	0.020<T	0.0055		0.890	0.003<	8.03	0.2 <W	0.0090	0.190
850911	0950	34803	0.038	0.030<T	0.0050		0.540	0.003<	7.97	0.3 <T	0.0135	0.059
851009	0940	34848	0.026	0.160	0.0175		0.560	0.003<	7.91	0.2 <T	0.0300	0.121
851112	1015	34905	0.054	5.640	0.0735		1.360	0.003<	7.73	0.3 <T	0.155	0.445
851204	1105	34947	0.056	1.550	0.0750		1.050		7.94	0.3 <T	0.0945	0.243
860106	0935	24711	0.092	1.270	0.0300		0.900	0.003<	7.93	0.5 <T	0.0450	0.105
860205	1035	24838	0.218	1.140	0.0325		0.950	0.006	7.45	4.2	0.0395	0.113
860303	0945	24885	0.092	1.280	0.0175		0.900	0.007	7.76	0.2 <W	0.0140	0.103
860414	0910	24951	0.056	1.210	0.0250		0.800	0.007	8.09	0.3 <T	0.0135	0.110
860505	0910	25009	0.074	0.405	0.0165		0.925	0.003<	7.99	2.2	0.0105	0.163
860612	0930	25059	0.040	0.765	0.0235		1.050	0.003<	7.95	0.5 <T	0.0335	0.290
860707	1010	25117	0.018	0.190	0.0215		0.900	0.014	7.94	3.4 LIC	0.0320	0.155
860806	0945	25149	0.020	0.280	0.0255		0.900	0.006	8.35	0.3 <T	0.0570	0.230
860911	0950	25207	0.024	0.245	0.0165		0.650	0.003<	8.20	0.5 <T	0.0400	0.150
		MAXIMUM	0.640	10.300	0.2290	8.680	6.500	0.043	8.35	4.2	0.2430	0.950
		ARITH MEAN	0.093<A	1.409<A	0.031	1.427	1.12	0.003	7.90	1 <A	0.044	0.183
		GEOM MEAN	0.041<A	0.750<A	0.019	0.697	0.93		7.90		0.031	0.145
		MINIMUM	0.004	0.015	0.002	0.005	0.210	0.003	5.94	-0.6	0.004	0.013
		STD DEV (GEOM *)	0.154<A	1.665<A	0.038	1.631	0.81		0.27		0.043	0.145
		# SAMP IN STATISTICS	93	65	92	64	93	31	93	59	93	93
		% SAMP (EXCLUDED)						64		22		

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	P1ALDR ALDRIN NG/L	P1BHCA BHC ALPHA NG/L	P1BHCB BHC BETA NG/L	P1BHCG BHC GAMMA NG/L	P1CHLA CHLRDANE ALPHA NG/L	P1CHLG CHLRDANE GAMMA NG/L	P1DIEL DIELDRIN NG/L	P1DMDT DMDT METHXYLLR NG/L	P1ENDR ENDRIN NG/L	P1ENDS ENDOSULP SULPHATE NG/L
810423	1020	38479	1<W	2	1<W	1	2<W	2<W	2<W	3	4<W	4<W
810513	0920	38520	1<W	2	1<W	1	2<W	2<W	2<W	5<W	4<W	4<W
810611	0920	38554	1<W	3	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
810728	0900	38601	1<W	3	1<W	1	2<W	2<W	2<W	5<W	4<W	4<W
810924	0950	38705	1<W	5	1<W	1	2<W	2<W	2<W	5<W	4<W	4<W
811008	0950	38752	1<W	3	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
811217	0840	38831	1<W	10	1<W	1	2<W	2<W	2<W	5<W	4<W	4<W
820121	1045	48339	1<W	15	7	2	2<W	2<W	2<W	5<W	4<W	4<W
820311	0910	48436	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
820415	0850	48491	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
820513	0925	48570	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W

(C O N T D)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-005-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
006
5409

LAT: 43 05 27.94 LONG: 079 46 06.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM		TEST-NAME:	P13LDR	P18HCA	P13HCB	P18HCG	P1CHLA	P1CHLG	P1DIEL	P1DMDT	P1ENDR	P1ENDS
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	ALDRIN NG/L	BHC ALPHA NG/L	BHC BETA NG/L	BHC GAMMA NG/L	CHLRDANE ALPHA NG/L	CHLRDANE GAMMA NG/L	DIELDRIN NG/L	DMDT METHXYLLR NG/L	ENDRIN NG/L	ENDOSULF SULPHATE NG/L
820622	0905	46612	1<W	5	1<W	5	2<W	2<W	2<W	5<W	4<W	4<W
820706	1035	46657	1<W	4	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
820809	1000	46710	1<W	4	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
820902	0930	46799	1<W	5	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
821005	0935	46840	1<W	4	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
821104	0915	46900	1<W	5	4	1<W	2<W	2<W	2<W	5<W	4<W	4<W
821209	0855	46964	1<W	4	1<W	4	2<W	2<W	2<W	5<W	4<W	4<W
830105	0835	25509	1<W	4	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
830210	0915	25556	1<W	4	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
830308	0930	25613	1<W	1	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
830406	0925	25658	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
830502	0900	25721	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
830616	0925	28771	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
830704	1135	28816	1<W	4	1<W	2	2<W	2<W	2<W	5<W	4<W	4<W
830810	0910	25851	1<W	3	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
830901	0955	25906	1<W	4	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
831004	0920	25951	1<W	3	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
831102	1025	25756	1<W	3	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
831205	0840	23802	1<W	4	1<W	1	2<W	2<W	2<W	5<W	4<W	4<W
840202	1125	64758	1<W	4	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
840305	1015	64799	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
840409	0905	64858	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
840507	0925	64920	1<W	3	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
840604	0915	65051	1<W	4<T	1<W	3<T	2<W	2<W	2<W	5<W	4<W	4<W
840703	0910	65111	1<W	3<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
840813	0925	65175	1<W	3<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
840912	1145	65205	1<W	4<T	1<W	2<T	2<W	2<W	2<W	5<W	4<W	4<W
841010	1450	65250	1<W	2<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
841108	0930	65303	1<W	3<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
841203	0955	65350	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850102	0915	34715	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850204	0940	34759	1<W	2<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850306	0935	34806	1<W	3<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850401	1010	34850	1<W	2<T	1<W	1<T	2<W	2<W	2<W	5<W	4<W	4<W
850506	1010	34928	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850605	0940	34978	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850716	1015	35071	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850820	1030	35095	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
850911	0950	34603	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
851009	0940	34849	1<W	2<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
851112	1015	34908	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W

(C O N T D)

S.O.W.A SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0600300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:			P1ALDR	P1BHCA	P1BHCB	P1BHCG	P1CHLA	P1CHLG	P1DIEL	P1DMDT	P1ENDR	P1ENDS
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	ALDRIN NG/L	BHC ALPHA NG/L	BHC BETA NG/L	BHC GAMMA NG/L	CHLRDANE ALPHA NG/L	CHLRDANE GAMMA NG/L	DIELDRIN NG/L	DMDT MTHXYLLR NG/L	ENDRIN NG/L	ENDOSULP SULPHATE NG/L
851204	1105	34947	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
860106	0935	24711	1<W	1<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
860205	1035	24835	1<W	2<T	1<W	2<T	2<W	2<W	2<W	5<W	4<W	4<W
860303	0945	24885	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
860414	0910	24951	1<W	1<W	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
860505	0910	25009	1<W	2<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
860707	1010	25117	1<W	2<T	1<W	1<T	2<W	2<W	2<W	5<W	4<W	4<W
860806	0945	25149	1<W	1<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
860911	0950	25207	1<W	1<T	1<W	1<W	2<W	2<W	2<W	5<W	4<W	4<W
		MAXIMUM	1	15	7	4	2	2	2	5	4	4
		ARITH MEAN	1<A	5<A	1<A	1<A	2<A	2<A	2<A	5<A	4<A	4<A
		GEOM MEAN	1<A	2<A	1<A	1<A	2<A	2<A	2<A		4<A	4<A
		MINIMUM	1	1	1	1	2	2	2	0	4	4
		STD DEV (GEOM *)	0<A	3<A	1<A	1<A	0<A	0<A	0<A		0<A	0<A
		# SAMP IN STATISTICS	61	61	61	61	61	61	61	61	61	61
		% SAMP (EXCLUDED)										

*=INTERIM TEST-NAME:			P1END1	P1END2	P1HEPE	P1HEPT	P1MIRX	P1OCHL	P1OPDT	P1PCBT	P1PPDD	P1PPDE
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	ENDOSULP I NG/L	ENDOSULP II NG/L	HEPE NG/L	HEPACHOR NG/L	MIREX NG/L	OXCHLANE NG/L	OP-DDT NG/L	PCB TOTAL NG/L	PP-DDD NG/L	PP-DDE NG/L
810202	0940	38554								20<W		
810309	0935	33401								20<W		
810423	1020	39479	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
810513	0920	39520	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
810611	0920	39554	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
810728	0900	38601	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
810924	0950	38705	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
811008	0950	38752	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
811217	0940	38891	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820121	1045	48339	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820311	0910	48434	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820415	0950	43491	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820513	0925	48570	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820622	0905	43612	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820706	1035	48657	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820809	1000	43710	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
820902	0930	48799	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W

(C O N T D)

S.O.W.7 SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02 004 5400

LAT: 43 05 27.94 LONG: 079 46 05.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

**INTERIM TEST-NAME:			P1ENDT	P1END2	P1HEPE	P1HEPT	P1MIRX	P1OCHL	P1DPDT	P1PCBT	P1PPDD	P1PPDE
SAMPLE DATE YYMMDD	HOUR LAT	SAMPLE NUMBER	ENDOSULP I NG/L	ENDOSULP II NG/L	HEPE NG/L	HEPACHOR NG/L	MIREX NG/L	OXCHLANE NG/L	DP-DDT NG/L	PCB TOTAL NG/L	PP-DDD NG/L	PP-DDE NG/L
821005	0955	43840	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
821104	0915	43900	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
821209	0955	43964	2<W	4<W	1<W	1<W	5<W	2<W	5<W	5<W	5<W	1
830105	0935	23509	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830210	0915	23556	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830308	0930	23613	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830406	0925	23658	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830502	0900	23721	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830616	0925	23771	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830704	1135	23816	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830810	0910	23851	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
830901	0955	23906	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
831004	0920	23951	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
831102	1025	23756	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
831205	0940	23802	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840202	1125	64758	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840305	1015	64799	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840409	0905	64858	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840507	0925	64920	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840604	0915	65051	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840703	0910	65111	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840813	0925	65175	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
840912	1145	65205	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
841010	1450	65250	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
841108	0930	65303	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
841203	0955	65350	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850102	0915	34715	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850204	0940	34759	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850306	0955	34806	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850401	1010	34850	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850506	1010	34928	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850605	0940	34978	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850716	1015	35071	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850820	1030	35045	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
850911	0950	34803	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
851009	0940	34848	2<W	4<W	1<W	1<W	5<W	2<W	5<W	150P42	5<W	1<W
851112	1015	34908	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
851204	1105	34947	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
860106	0955	24711	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
860205	1035	24838	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
860303	0945	24845	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W

(C O N T D)

MOE - SAMPLE INFORMATION SYSTEM R4.3 STATION DETAIL REPORT DATE OF REPORT: 1 MAY 87 PAGE: 30

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-005-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0500300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:		P1END1	P1END2	P1HEPE	P1HEPT	P1MIRX	P1OCHL	P1OPDT	P1PCBT	P1PPDD	P1PPDE
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	ENDOSULP I NG/L	ENDOSULP II NG/L	HEPE NG/L	HEPACHOR NG/L	MIREX NG/L	OXCHLANE NG/L	OP-DDT NG/L	PCB TOTAL NG/L	PP-DDD NG/L	PP-DDE NG/L
860414	0910	24951	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
860505	0910	25009	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
860707	1010	25117	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
860806	0945	25149	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
860911	0950	25207	2<W	4<W	1<W	1<W	5<W	2<W	5<W	20<W	5<W	1<W
		MAXIMUM	2	4	1	1	5	2	5	100	5	1
		ARITH MEAN	2<A	4<A	1<A	1<A	5<A	2<A	5<A	22<A	5<A	1<A
		GEOM MEAN	2<A	4<A	1<A	1<A	5<A	2<A	5<A	20<A	5<A	1<A
		MINIMUM	2	4	1	1	5	2	5	5	5	1
		STD DEV (GEOM *)	0<A	0<A	0<A	0<A	0<A	0<A	0<A	19<A	0<A	0<A
# SAMP IN STATISTICS			61	61	61	61	61	61	61	63	61	61
% SAMP (EXCLUDED)												

*=INTERIM TEST-NAME:		P1PPDT	P1TOX	RSF	RSP	RST	SSO4UR	TCMF	TCMFBK	TURB	XTHCRD
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	PP-DDT NG/L	TOXAPHEN NG/L	RESIDUE FILTERED MG/L	RESIDUE PARTIC. MG/L	RESIDUE TOTAL MG/L	SULPHATE UNF.REAC MG/L AS SO4	COLIFORM TOTAL MF CNT /100ML	COLIFORM TOTAL MF BCKGRD CNT /100ML	TURBIDITY FTU	HXCHLORD BUTADINE NG/L
790110	1005	45318			360.00	9.00	369.00	109.000	200AIC	900	13.00	
790226	1340	45362			127.000	24.00	155.00	35.000	1000AIC	7900	54.00	
790306	1007	45402			202.000	22.00	224.00	60.000	1000<	1000	55.00	
790418	1020	45465			247.000	36.00	283.00	60.000	130	1400	49.00	
790509	0925	45529			439.00	76.00	365.00	182.000	5700	6300	47.00	
790620	1015	45568			559	115	554	135	6000	43000	74	
790718	1035	45618			614.00	75.00	589.00	195.000	17000	34000	43.00	
790827	1017	45648			202.000	22.00	224.00	27.500	19000	45000	20.00	
790917	0945	45691			472.00	40.00	512.00	142.000	3100	34000	35.00	
791015	1005	48750			352.00	47.00	409.00	55.000	1700	4900	47.00	
791122	0730	45791			285.00	17.00	302.00	78.000	1000AIC	32000	15.00	
791227	1055	48853			200	22.0	222.0	70.0	3700	17000	200	
800130	1010	23358			348.00	13.00	361.00	89.000	100AIC	10000	70.00	
800227	1050	23375			436.00	58.00	494.00	134.000	1100	13000	65.00	
800319	0945	23397			199.000	156.00	355.00	53.500	24000	250000	210.00	
800415	1000	23453			199.000	481.00	670.00	67.500	41000	170000	360.00	
800506	1015	23501			396.00	103.00	499.00	107.000	600AIC	7100	55.00	
800609	0740	23530			592.00	103.00	695.00	207.000	3300	140000	73.00	
800715	1000	23595			904	54	958	303.000	630	43000	37.00	
800911	1005	23643			494	52	545	115			55	

(CONTD)

E.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02 004 5400

LAT: 43 05 27.94 LONG: 079 45 06.02 U T M: 17 0500300.0 4767750.0 4 · REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LAT	SAMPLE NUMBER	PP-DDT MG/L	TOXAPHEN MG/L	RSP RESIDUE FILTERED MG/L	RSP RESIDUE PARTIC. MG/L	RST RESIDUE TOTAL MG/L	SSO4UR SULPHATE UNF.READ MG/L AS SO4	TLMF COLIFORM TOTAL MF CNT /100ML	TLMFBK COLIFORM TOTAL MF BCKGRD CNT /100ML	TURB TURBIDITY FTU	XTMCBD MXCMLORD BUTADINE NG/L
800908	0955	23693			30.000	52.00	152.00	63.500	30000	36500	5.50	
801007	0940	23737			237.00	22.00	309.00	72.500	1100	13500	20.00	
801117	0950	23736			337.00	9.00	345.00	90.000	700AID	3300	13.00	
801217	0900	23825			307.00	51.00	353.00	234.000	3000AID	9000	57.00	
810122	1305	33331			933.00	25.00	961.00	333.000	1000	1900	13.00	
810202	0940	33334			644.00	24.00	968.00	313.000	123000	36000	18.00	
810309	0935	33401			721	5		252.000	30<=>	1160	3.80	
810423	1020	33479	5<W		699	32		235	260	3000>	2.20	
810513	0920	33520	5<W		599	55		253	3200	30000>	30.00	
810611	0920	33564	5<W		731	85		285	2200<=>	45000	44.00	
810728	0900	33601	5<W		505	133.0		140.0	12000	134000	7.90	
810831	0940	33673			575	85.0		197.0	5200<=>	126000	5.70	
810924	0930	33705	5<W		249	63.7		82.0	19000	170000	85.00	
811008	0950	33752	5<W					110.0	19000	140000	53.00	
811105	0915	33796			346	22.2		113.0	2200	7500	19.10	
811217	0840	33831	5<W		264	15.1		63.0	40<=>	1220	17.50	
820121	1045	43339	5<W		376	3.5		89.0	430	960	13.50	
820311	0910	43434	5<W		612.0	5.400		141.0	520	2500	5.40	
820415	0550	43491	5<W		394.0	41.400		82.5	2000	5700	55.00	
820513	0925	43570	5<W		955.0	52.500		377.0	1400	26000	61.00	
820622	0905	43612	5<W		410.0	315.000		92.5	31000<=>	470000	375.00	
820706	1035	43657	5<W		395.0	182.000		93.5	4300<=>	27000	127.00	
820809	1000	43710	5<W		503.0	85.500		129.0	10300<=>	49000	72.00	
820902	0930	43779	5<W		525.0	114.000		135.9	16300<=>	54000	84.00	
821005	0935	43840	5<W		356.0	46.700		173.6	2800<=>	43000	52.00	
821104	0915	43900	5<W		391.0	134.000		95.30	74000<=>	520000	137.00	
821209	0855	43954	5<W		430.0	105.000		93.60	1000	3700	57.00	
830105	0835	23539	5<W		394.0	19.390		90.50	120<=>	3000	42.00	
830210	0915	23555	5<W		354.0	20.400		95.50			27.00	
830308	0930	23613	5<W		448.0	95.300		154.60	1000<=>	33000	123.00	
830406	0925	23658	5<W		506.0	75.500		127.85			90.00	
830502	0900	23721	5<W		412.0	221.000		94.55	31000<=>	730000		
830616	0925	23771	5<W		597.0	95.000		193.00			100.00	
830704	1135	23816	5<W		667.0	77.400		223.00	5000<=>	130000	75.00	
830810	0910	23851	5<W		509.0	97.100		125.50			81.00	
830901	0955	23906	5<W		404.0	113.000		92.95	2300<=>	76000	90.00	
831004	0920	23951	5<W									
831102	1025	23756	5<W		301.0	29.700		92.15	1100	6500	33.00	
831205	0840	23802	5<W		412.0	10.100		135.50			35.00	
840104	0905	64709			408.0	17.700		152.40	130<=>	1140	30.00	

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-0004-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0500530.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LAT	SAMPLE NUMBER	PP-DDT NG/L	TOXAPHEN NG/L	RSF RESIDUE FILTERED MG/L	RSP RESIDUE PARTIC. MG/L	RST RESIDUE TOTAL MG/L	SSO4UR SULPHATE UNF.READ MG/L AS SO4	TCMF COLI-FORM TOTAL MF CNT /100ML	TCMFBG COLIFORM TOTAL MF BCKGRD CNT /100ML	TURB TURBIDITY FTU	XTHLBD MXCHLORD SUTADINE NG/L
840202	1125	64758	5<W		646.0	27.100		227.50			22.00	
840305	1015	64799	5<W		420.0	15.300		113.50	150<=>	5000	27.00	
840409	0905	64858	5<W		247.0	45.700		55.16			64.00	
840507	0925	64920	5<W		422.0	131.900		125.50	2600	24000	92.00	
840604	0915	65051	5<W		500.0	175.400		67.55			135.00	1<W
840703	0910	65111	5<W		410.0	109.200		135.50	1500<=>	50000	77.00	1<W
840813	0925	65175	5<W		605.0	101.300		185.40			85.00	1<W
840912	1145	65205	5<W		432.0	223.000		93.58	50000<=>	840000	172.00	1<W
841010	1450	65250	5<W		358.0	110.700		65.56			92.00	1<W
841108	0930	65303	5<W		350.0	25.900		83.97	21000	255000	35.00	1<W
841203	0955	65350	5<W		340.0	15.240		87.46			22.00	1<W
850102	0915	34715	5<W		336.0	65.050		81.76	25000<=>	520000	122.00	1<W
850204	0940	34759	5<W		332.0	37.140		525.90			32.00	1<W
850306	0935	34806	5<W		376.0	54.990		84.90	6000<=>	12000	45.00	1<W
850401	1010	34850	5<W		328.0	542.400		50.70				1<W
850506	1010	34928	5<W		510.0	71.930		172.55	400<=>	28500	55.00	1<W
850605	0940	34978	5<W		530.0	113.200		183.90			92.00	1<W
850716	1015	35071	5<W		846.0	55.020		347.50	200<=>	55000	70.00	1<W
850820	1030	35095	5<W		1128.5	129.600		505.00			50.00	1<W
850911	0950	34803	5<W		1245.4	26.250		573.50	1500<=>	50000	27.00	1<W
851009	0940	34846	5<W		358.0	40.520		101.75			112.00	1<W
851112	1015	34908	5<W		227.5 CRD			64.50	121000<=>	570000	200.00*	1<W
851204	1105	34947	5<W		316.0	40.560		22.75			145.00	1<W
860106	0955	24711	5<W		536.0	25.460		203.00	550	5200	41.00	1<W
860205	1035	24858	5<W		340.0	23.590		111.00			55.00	1<W
860303	0945	24935	5<W		708.0	57.210		254.00	620	3500	24.00	1<W
860414	0910	24951	5<W		300.0	47.1		67.30			49.00	1<W
860505	0910	25009	5<W		601.0	110.0		193.00	400<=>	25000	110.00	1<W
860612	0930	25059			552.0	126.0		175.00			159.00	
860707	1010	25117	5<W		554.0	83.5		154.00			97.00	1<W
860806	0945	25149	5<W	NO DATA|NF	498.0	155.0		132.00			152.00	1<W
860911	0950	25207	5<W	NO DATA|NF	NO DATA|LC	NO DATA|LC		67.25			95.00	1<W
		MAXIMUM	5		1246.4	542.400	261.00	575.00	121000	540000	375.00	1
		ARITH MEAN	5<W		475	80	483	145	3625	44587	70	1<W
		GEOM MEAN	5<W		450	53	429	121				1<W
		MINIMUM	5		30.000	5	132.00	22.75	40	900	2.20	1
		STD DEV (GEOM =)	0<W		215	87	247	93				1<W
		# SAMP IN STATISTICS	51		39	54	25	91	55	53	57	27
		% SAMP (EXCLUDED)							1	2	1	

(CONTD)

MOE - SAMPLE INFORMATION SYSTEM R4.5 STATION DETAIL REPORT DATE OF REPORT: 1 MAY 87 PAGE: 55

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0600300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	X2HCB HCB NG/L	X2HCE HCE NG/L	X2DCST DCTCHLOR STYRENE NG/L	X2PNCB PENTA CHLORO BENZENE NG/L	X2T236 2,3,6 TRCHLORO TOLUENE NG/L	X2T245 2,4,5 TRCHLORO TOLUENE NG/L	X2T2E4 2,5,4 TRCHLORO TOLUENE NG/L	X2T23 1,2,3 TRCHLORO BENZENE NG/L	X21234 1,2,3,4 TECHLORO BENZENE NG/L	X21235 1,2,3,5 TECHLORO BENZENE NG/L
810423	1020	38479	1<W									
810513	0920	38520	1<W									
810611	0920	38554	1<W									
810728	0900	38601	1<W									
810924	0950	38705	1<W									
811008	0950	38752	1<W									
811217	0840	38881	1<W									
820121	1045	48339	1<W									
820311	0910	48434	1<W									
820415	0850	48491	1<W									
820513	0925	48570	1<W									
820622	0905	48612	1<W									
820706	1035	48657	1<W									
820809	1000	48710	1<W									
820902	0930	48799	1									
821005	0935	48840	1<W									
821104	0915	48900	1<W									
821209	0855	48964	1<W									
830105	0835	28509	1<W									
830210	0915	28556	1<W									
830308	0930	28613	1<W									
830406	0925	28658	1<W									
830502	0900	28721	1<W									
830616	0925	28771	1<W									
830704	1135	28816	1<W									
830810	0910	28851	1<W									
830901	0955	28906	1<W									
831004	0920	28951	1<W									
831102	1025	28755	1<W									
831205	0840	28802	1<W									
840202	1125	64758	1<W									
840305	1015	64799	1<W									
840409	0905	64855	1<W									
840507	0925	64920	1<W									
840604	0915	65061	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
840703	0910	65111	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
840813	0925	65175	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
840912	1145	65205	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
841010	1450	65250	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
841108	0930	65303	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
841203	0955	65350	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 45 06.02 U T M: 17 0500300.0 4767750.0 N REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:			X2HCB	X2HCE	X2DCST	X2PNCB	X2T236	X2T245	X2T254	X2123	X21234	X21235
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	HCB NG/L	HCE NG/L	DCTCHLOR STYRENE NG/L	PENTA CHLORO BENZENE NG/L	2,3,6 TRCHLORO TOLUENE NG/L	2,4,5 TRCHLORO TOLUENE NG/L	2,5,4 TRCHLORO TOLUENE NG/L	1,2,3 TRCHLORO BENZENE NG/L	1,2,3,4 TECHLORO BENZENE NG/L	1,2,3,5 TECHLORO BENZENE NG/L
850102	0915	34715	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
850204	0940	34759	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
850306	0935	34806	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
850401	1010	34850	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
850506	1010	34928	1<W	1<W		1<W	5<W	5<W	5<W	5<W	1<W	1<W
850605	0940	34979	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
850716	1015	35071	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
850820	1030	35095	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
850911	0950	34803	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
851009	0940	34846	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
851112	1015	34908	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
851204	1105	34947	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860106	0935	24711	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860205	1035	24835	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860303	0945	24885	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860414	0910	24951	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860505	0910	25009	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860707	1010	25117	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860806	0945	25149	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
860911	0950	25207	1<W	1<W	1<W	1<W	5<W	5<W	5<W	5<W	1<W	1<W
		MAXIMUM	1	1	1	1	5	5	5	5	1	1
		ARITH MEAN	1<A	1<A	1<A	1<A	5<A	5<A	5<A	5<A	1<A	1<A
		GEOM MEAN	1<A	1<A	1<A	1<A	5<A	5<A	5<A	5<A	1<A	1<A
		MINIMUM	1	1	1	1	5	5	5	5	1	1
		STD DEV (GEOM *)	0<A	0<A	0<A	0<A	0<A	0<A	0<A	0<A	0<A	0<A
		# SAMP IN STATISTICS	61	27	26	27	27	27	27	27	27	27
		% SAMP (EXCLUDED)										

(CONTD)

P.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0031-039-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 03 27.94 LONG: 079 46 06.02 U T M: 17 0503300.0 4767750.0 4 . REGION: 06 DISTANCE: 101.225

**INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LAT	SAMPLE NUMBER	X2124 1,2,4 TRCHLORO BENZENE NG/L	X21245 1,2,4,5 TECHLORO BENZENE NG/L	X2135 1,3,5 TRCHLORO BENZENE NG/L	ZNUT ZINC UNF.TOT. MG/L AS ZN
790110	1005	43318				0.030
790226	1340	43362				0.020
790308	1007	43402				0.030
790418	1020	43455				0.020 <
790509	0925	43529				0.01 <
790620	1015	43568				0.01 <
790718	1035	43618				0.020
790827	1017	43648				0.010 <
790917	0945	43681				0.020
791015	1005	43750				0.010 <
791122	0930	43791				0.010 <
800130	1010	23338				0.050
800227	1030	23373				0.030
800319	0945	23397				0.040
800415	1000	23453				0.120
800506	1015	23501				0.010 <
800609	0940	23580				0.030
800715	1000	23595				0.01 <
800811	1005	23643				0.012
800908	0935	23693				0.007
801007	0940	23737				0.003
801117	0950	23786				0.0060
801217	0900	23825				0.049
810122	1305	33331				0.0140
810202	0940	33364				0.0110
810309	0935	33401				0.004
810513	0920	33520				0.006
810611	0920	33554				0.012
810728	0900	33601				0.018
810831	0940	33673				0.011
810924	0950	33705				0.014
811008	0950	33752				0.012
811105	0915	33796				0.009
811217	0940	33881				0.003
820121	1045	43339				0.004
820311	0910	43434				0.010
820415	0950	43491				0.010
820513	0925	43570				0.012
820622	0905	43612				0.057
820609	1000	43710				0.018
820902	0930	43799				0.013

(CONTD)

B.O.W./ SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIVER

STATION ID: 11-0001-004-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5400

LAT: 43 05 27.94 LONG: 079 45 06.02 UTM: 17 0603300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:			X2124	X2124S	X2135	ZNUT
			1,2,4	1,2,4,5	1,3,5	ZINC
SAMPLE DATE YYMMDD	HOUR LMT	SAMPLE NUMBER	TRCHLORO BENZENE NG/L	TRCHLORO BENZENE NG/L	TRCHLORO BENZENE NG/L	UNF.TOT. MG/L AS ZN
821005	0935	43840				0.008
821104	0915	43930				0.026
821209	0955	43964				0.012
830105	0935	23509				0.006
830210	0915	23556				0.005
830308	0930	23613				0.019
830406	0925	23658				0.018
830502	0900	23721				0.022
830616	0925	23771				0.014
830704	1135	23816				0.012
830810	0910	23851				0.011
830901	0955	23906				0.012
831102	1025	23756				0.009
831205	0340	23802				0.008
840104	0905	64709				0.006
840202	1125	64755				0.005
840305	1015	64799				0.014
840409	0905	64858				0.010
840507	0925	64920				0.012
840604	0915	65021	5<W	1<W	5<W	0.022
840703	0910	65111	5<W	1<W	5<W	0.012
840813	0925	65175	5<W	1<W	5<W	0.014
840912	1145	65205	5<W	1<W	5<W	0.017
841010	1450	65250	5<W	1<W	5<W	0.014
841108	0930	65305	5<W	1<W	5<W	0.006
841203	0955	65350	5<W	1<W	5<W	0.004
850102	0915	34715	5<W	1<W	5<W	0.022
850204	0940	34759	5<W	1<W	5<W	0.012
850306	0935	34806	5<W	1<W	5<W	0.007
850401	1010	34850	5<W	1<W	5<W	0.054
850506	1010	34928	5<W	1<W	5<W	0.012
850605	0940	34978	5<W	1<W	5<W	0.017
850716	1015	35071	5<W	1<W	5<W	0.009
850820	1030	35095	5<W	1<W	5<W	0.011
850911	0950	34803	5<W	1<W	5<W	0.009
851009	0940	34848	5<W	1<W	5<W	0.016
851112	1015	34908	5<W	1<W	5<W	0.034
851204	1105	34947	5<W	1<W	5<W	
860106	0935	24711	5<W	1<W	5<W	0.009
860205	1035	24838	5<W	1<W	5<W	0.013
860303	0945	24855	5<W	1<W	5<W	0.012

(CONTD)

S.O.W.7 SITE: WELLAND RIVER
SAMPLE POINT: AT SINCLAIRVILLE BRIDGE
STATION TYPE: RIV-R

STATION ID: 11-0001-008-02

MAJOR BASIN: GREAT LAKES
MINOR BASIN: LAKE ONTARIO
TERM STREAM: WELLAND RIVER

STORET CODE: 02
004
5409

LAT: 43 05 27.94 LONG: 079 45 06.02 U T M: 17 0603300.0 4767750.0 4 REGION: 02 DISTANCE: 101.225

*=INTERIM TEST-NAME:

SAMPLE DATE YYMMDD	HOUR LAT	SAMPLE NUMBER	X2124 1,2,4 TRICHLORO BENZENE NG/L	X21245 1,2,4,5 TRICHLORO BENZENE NG/L	X2135 1,3,5 TRICHLORO BENZENE NG/L	ZNUT ZINC UNF.TOT. MG/L AS ZN
860414	0910	24951	5<W	1<W	5<W	0.013
860505	0910	25009	5<W	1<W	5<W	0.016
860612	0950	25059				0.032
860707	1010	25117	5<W	1<W	5<W	0.012
860806	0945	25149	5<W	1<W	5<W	0.023
860911	0950	25207	5<W	1<W	5<W	0.013
		MAXIMUM	5	1	5	0.120
		ARITH MEAN	5<A	1<A	5<A	0.017
		GEOM MEAN	5<A	1<A	5<A	
		MINIMUM	5	1	5	0.003
		STD DEV (GEOM *)	0<A	0<A	0<A	
# SAMP IN STATISTICS			27	27	27	79
% SAMP (EXCLUDED)						9

RIVER BASIN	STREAM	SAMPLE POINT DESCRIPTION	DISTANCE	LOCATION CODE	G.O.M. INDEX	PAGE NO.
WELLAND RIVER	WELLAND RIVER	AT BRIDGE SOUTH OF WELLAND AIRPORT	56.533	11-0001-007-02	2 A-01	1
	WELLAND RIVER	AT SINCLAIRVILLE BRIDGE	101.225	11-0001-009-02	2 B-01	15

PROGRAM: 01 WATER MANAGEMENT
STUDY: 002 INLAND WATER QUALITY MONITORING

11-0001-007-02 WELLAND RIVER
SAMPLE POINT DESC : AT BRIDGE SOUTH OF WELLAND AIRPORT
STATION TYPE/PLANT : RIVER
MAJOR/MINOR BASIN : GREAT LAKES
TERMINAL STREAM : WELLAND RIVER
MUNICIPALITY DESC :
GEOG CO-ORDINATES : LAT: 42591879 LONG: 079190545 7
CONFIDENTIAL:
LAKE ONTARIO
DISTANCE (KM): 35.555
MUNIC CODE: 65604 CONCESSION:
U.T.M.: 17 0637150.0 4753950.0 4
SETUP DATE: 77 10 01
TERM DATE:
REGION: 02 DISTRICT:
MAJOR: 02 MINOR: 004
STREAM CODE: 5400
LOT: ELEV:
AGENCY:

11-0001-009-02 WELLAND RIVER
SAMPLE POINT DESC : AT SINCLAIRVILLE BRIDGE
STATION TYPE/PLANT : RIVER
MAJOR/MINOR BASIN : GREAT LAKES
TERMINAL STREAM : WELLAND RIVER
MUNICIPALITY DESC :
GEOG CO-ORDINATES : LAT: 43032794 LONG: 079460602 7
CONFIDENTIAL:
LAKE ONTARIO
DISTANCE (KM): 101.225
MUNIC CODE: 65004 CONCESSION:
U.T.M.: 17 0600300.0 4767750.0 4
SETUP DATE: 75 12 01
TERM DATE:
REGION: 02 DISTRICT:
MAJOR: 02 MINOR: 004
STREAM CODE: 5400
LOT: ELEV:
AGENCY:

TEST NAME	DESCRIPTION	ABREV DESCRIPTION	UNIT/SCALE
ACDT	ACIDITY, TOTAL	ACIDITY TOTAL	MILLIGRAM PER LITER AS CALCIUM CARBONATE
ALKT	ALKALINITY, TOTAL	ALK TOTAL	MILLIGRAM PER LITER AS CALCIUM CARBONATE
ALUT	ALUMINIUM, UNFILTERED TOTAL	ALUMINUM UNF.TOT.	MILLIGRAM PER LITER AS ALUMINIUM
ASUT	ARSENIC, UNFILTERED TOTAL	ARSENIC UNF.TOT.	MILLIGRAM PER LITER AS ARSENIC
BOD5	BOD, 5 DAY, TOTAL DEMAND	BOD 5 DAY TOT.DEM.	MILLIGRAM PER LITER AS OXYGEN
CAUR	CALCIUM, UNFILTERED REACTIVE	CALCIUM UNF.REAC	MILLIGRAM PER LITER AS CALCIUM
CCNAUR	CYANIDE, AVAIL, UNFIL.REAC	CYANIDE AVAIL UNF.REAC	MILLIGRAM PER LITER AS HYDROGEN CYANIDE
CDUT	CADMIUM, UNFILTERED TOTAL	CADMIUM UNF.TOT.	MILLIGRAM PER LITER AS CADIUM
CLIDUR	CHLORIDE, UNFIL.REAC	CHLORIDE UNF.REAC	MILLIGRAM PER LITER AS CHLORINE
COD	CHEMICAL OXYGEN DEMAND	CHEM. OX DEMAND	MILLIGRAM PER LITER AS OXYGEN
COLAP	COLOUR, APPARENT	COLOUR APPARENT	HAZEN COLOUR UNIT
CONDAM	CONDUCTIVITY, AMBIENT	CONDUCT. AMBIENT	MICROMHOS/CM (CONDUCTIVITY) AT AMBIENT TEMPERATURE
CONDZ5	CONDUCTIVITY, 25C	CONDUCT. 25C	MICROMHOS/CM (CONDUCTIVITY) AT 25 DEGREES CENTIGRADE

TEST NAME	DESCRIPTION	ABBREV DESCRIPTION	UNIT/SCALE
COUT	COBALT, UNFILTERED TOTAL	COBALT UNF.TOT.	MILLIGRAM PER LITER AS COBALT
CRUT	CHROMIUM, UNFILTERED TOTAL	CHROMIUM UNF.TOT.	MILLIGRAM PER LITER AS CHROMIUM
CUUT	COPPER, UNFILTERED TOTAL	COPPER UNF.TOT.	MILLIGRAM PER LITER AS COPPER (CUPRUM)
DO	DISSOLVED OXYGEN	DISSOLVED OXYGEN	MILLIGRAM PER LITER AS OXYGEN
DOC	CARBON, DISSOLVED ORGANIC	CARBON DISSOLVED ORGANIC	MILLIGRAM PER LITER AS CARBON
FAPRDP	PRECIPITATION GAUGE DEPTH	PRECIP DEPTH	MILLIMETER (.001 M)
FCMF	FECAL COLIFORM MF	FECAL COLIFORM MF	COUNTS PER 100 ML
FEUT	IRON, UNFILTERED TOTAL	IRON UNF.TOT.	MILLIGRAM PER LITER AS IRON (FERRUM)
FGPROJ	PROJECT/SUBPROJECT CODE	PROJECT SUB-PROJ CODE	
FSMF	FECAL STREPTOCOCCUS MF	FECAL STREPCUS MF	COUNTS PER 100 ML
FWDPTS	WATER DEPTH WHEN SAMPLED	WATER DEPTH	METER
FWPH	PH FIELD	PH FIELD	
FWSADP	SAMPLE DEPTH WHEN SAMPLED	SAMPLE DEPTH	METER

TEST NAME	DESCRIPTION	ABREV DESCRIPTION	UNIT/SCALE
FWSTAC	STREAM CONDITION	STREAM COND.	
FWTEMP	TEMPERATURE, WATER	WATER TEMP	DEGREES CELSIUS
HARDT	HARDNESS, TOTAL	HARDNESS TOTAL	MILLIGRAM PER LITER AS CALCIUM CARBONATE
HGUT	MERCURY, UNFILTERED TOTAL	MERCURY UNF.TOT.	MICROGRAM PER LITER AS MERCURY (HYDRARGYRUM)
IONCAL	ION BALANCE CALCULATION	ION BALANCE CALC.	
KKUR	POTASSIUM,UNFILTERED REACTIVE	POTASSIM UNF.REAC	MILLIGRAM PER LITER AS POTASSIUM (KALIUM)
MGUR	MAGNESIUM,FILTERED REACTIVE	MAGNESIM FIL.REAC	MILLIGRAM PER LITER AS MAGNESIUM
MNUT	MANGANESE,UNFILTERED TOTAL	MANGANSE UNF.TOT.	MILLIGRAM PER LITER AS MANGANESE
NAUR	SODIUM, UNFILTERED REACTIVE	SODIUM UNF.REAC	MILLIGRAM PER LITER AS SODIUM
NIUT	NICKEL, UNFILTERED TOTAL	NICKEL UNF.TOT.	MILLIGRAM PER LITER AS NICKEL
NNHTFR	AMMONIUM, TOTAL FILTER.REAC	NH3-N TOTAL FIL.REAC	MILLIGRAM PER LITER AS NITROGEN
NNOTFR	NITRATES TOTAL, FILTER.REAC	NO2+NO3N FIL.REAC	MILLIGRAM PER LITER AS NITROGEN
NNO2FR	NITRITE, FILTERED REACTIVE	NO2-N FIL.REAC	MILLIGRAM PER LITER AS NITROGEN

TEST NAME	DESCRIPTION	ABREV DESCRIPTION	UNIT/SCALE
NNO3FR	NITRATE, FILTERED REACTIVE	NO3-N FIL.REAC	MILLIGRAM PER LITER AS NITROGEN
NNTKUR	NITROGEN,TOT.KJELDAHL FIL.TOT	KJDAHL N TOTAL FIL.TOT.	MILLIGRAM PER LITER AS NITROGEN
PBUT	LEAD, UNFILTERED TOTAL	LEAD UNF.TOT.	MILLIGRAM PER LITER AS LEAD (PLUMBUM)
PH	PH (-LOG H+ CONCN)	PH	
PHNOL	PHENOLICS, UNFILERED REACTIVE	PHENOLS UNF-REAC	MICROGRAM PER LITER AS PHENOL
PPO4FR	PHOSPHATE,FILTERED REACTIVE	PO4 FIL.REAC	MILLIGRAM PER LITER AS PHOSPHORUS
PPUT	PHOSPHORUS,UNFILTERED TOTAL	PHOSPHOR UNF.TOT.	MILLIGRAM PER LITER AS PHOSPHORUS
P1ALDR	ALDRIN	ALDRIN	NANOGRAM PER LITER
P1BHCA	HEXACLORCYCLOHEX,ALPHA-BHC	BHC ALPHA	NANOGRAM PER LITER
P1BHCB	HEXACLORCYCLOHEX,BETA-BHC	BHC BETA	NANOGRAM PER LITER
P1BHCG	HEXACLORCYCLOHEX,GAMMA-BHC	BHC GAMMA	NANOGRAM PER LITER
P1CHLA	CHLORDANE,ALPHA	CHLRDANE ALPHA	NANOGRAM PER LITER
P1CHLG	CHLORDANE,GAMMA	CHLRDANE GAMMA	NANOGRAM PER LITER

TEST NAME	DESCRIPTION	ABREV DESCRIPTION	UNIT/SCALE
P1DIEL	DIELDRIN	DIELDRIN	NANOGRAM PER LITER
P1DMDT	DMDT METHOXYCHLOR	DMDT MTHXYLLR	NANOGRAM PER LITER
P1ENDR	ENDRIN	ENDRIN	NANOGRAM PER LITER
P1ENDS	ENDOSULFAN,SULPHATE	ENDOSULP SULPHATE	NANOGRAM PER LITER
P1END1	ENDOSULFAN I	ENDOSULP I	NANOGRAM PER LITER
P1END2	ENDOSULFAN II	ENDOSULP II	NANOGRAM PER LITER
P1HEPE	HEPTACHLOREPOXIDE	HEPE	NANOGRAM PER LITER
P1HEPT	HEPTACHLOR	HEPACHOR	NANOGRAM PER LITER
P1MIRX	MIREX	MIREX	NANOGRAM PER LITER
P1OCHL	OXYCHLORDANE	OXCHLANE	NANOGRAM PER LITER
P1OPDT	OP-DDT	OP-DDT	NANOGRAM PER LITER
P1PCBT	PCB TOTAL	PCB TOTAL	NANOGRAM PER LITER
P1PPDD	PP-DDD	PP-DDD	NANOGRAM PER LITER

TEST NAME	DESCRIPTION	ABREV DESCRIPTION	UNIT/SCALE
P1PPDE	PP-DDE	PP-DDE	NANOGRAM PER LITER
P1PPDT	PP-DDT	PP-DDT	NANOGRAM PER LITER
P1TOX	TOXAPHENE	TOXAPHEN	NANOGRAM PER LITER
RSF	RESIDUE,FILTERED	RESIDUE FILTERED	MILLIGRAM PER LITER
RSP	RESIDUE,PARTICULATE	RESIDUE PARTIC.	MILLIGRAM PER LITER
RST	RESIDUE,TOTAL	RESIDUE TOTAL	MILLIGRAM PER LITER
SAMPLE	SAMPLE NUMBER (FIELD)	SAMPLE NUMBER	
SIO3UR	SILICATES,UNFILTERED REACTIVE	SILICATE UNF.REAC	MILLIGRAM PER LITER AS SILICON
SSO4UR	SULPHATE, UNFILTERED REACTIVE	SULPHATE UNF.REAC	MILLIGRAM PER LITER AS SULPHATE
TCMF	COLIFORM, TOTAL MF	COLIFORM TOTAL MF	COUNTS PER 100 ML
TCMFBK	COLIFORM, TOTAL M/F BCKGRD	COLIFORM TOTAL MF BCKGRD	COUNTS PER 100 ML
TURB	TURBIDITY	TURBIDITY	FORMAZIN TURBIDITY UNIT
X1HC6D	HEXACHLOROBUTADIENE	HXCHLORO BUTADINE	NANOGRAM PER LITER

TEST NAME	DESCRIPTION	ABREV DESCRIPTION	UNIT/SCALE
X2HCB	HEXACHLOROBENZENE	HCB	NANOGRAM PER LITER
X2HCE	HEXACHLOROETHANE	HCE	NANOGRAM PER LITER
X2OCST	OCTACHLOROSTYRENE	OCTCHLOR STYRENE	NANOGRAM PER LITER
X2PNCB	PENTACHLOROBENZENE	PENTA CHLORO BENZENE	NANOGRAM PER LITER
X2T236	TRICHLOROTOLUENE 2,3,6	2,3,6 TRCHLORO TOLUENE	NANOGRAM PER LITER
X2T245	TRICHLOROTOLUENE 2,4,5	2,4,5 TRCHLORO TOLUENE	NANOGRAM PER LITER
X2T26A	TRICHLOROTOLUENE 2,6,A	2,6,A TRCHLORO TOLUENE	NANOGRAM PER LITER
X2123	TRICHLOROBENZENE 1,2,3	1,2,3 TRCHLORO BENZENE	NANOGRAM PER LITER
X21234	TETRACHLOROBENZENE 1,2,3,4	1,2,3,4 TECHLORO BENZENE	NANOGRAM PER LITER
X21235	TETRACHLOROBENZENE 1,2,3,5	1,2,3,5 TECHLORO BENZENE	NANOGRAM PER LITER
X2124	TRICHLOROBENZENE 1,2,4	1,2,4 TRCHLORO BENZENE	NANOGRAM PER LITER
X21245	TETRACHLOROBENZENE 1,2,4,5	1,2,4,5 TECHLORO BENZENE	NANOGRAM PER LITER
X2135	TRICHLOROBENZENE 1,3,5	1,3,5 TRCHLORO BENZENE	NANOGRAM PER LITER

TEST NAME	DESCRIPTION	ABREV DESCRIPTION	UNIT/SCALE
ZNUT	ZINC, UNFILTERED TOTAL	ZINC UNF.TOT.	MILLIGRAM PER LITER AS ZINC

APPENDIX K
1986 DATA TABLES

APPENDIX K
1986 DATA TABLES

1986 data obtained for water, snow and sediment quality are included in Tables K2 through K57. The data are discussed in Sections 3.6.4 through 3.6.8. A glossary for use with the tables is included in Table K1.

Water quality data have been organized into the following parameter groupings:

- General Chemistry
- Nutrients and Bacteriological
- Trace Constituents
- Priority Organics
  - Volatiles
  - Acid Extractables
  - Base/Neutral Extractables
  - PAH, PCB
  - Pesticides and Herbicides

Tables K2 through K25 contain Welland River water quality data. These data are discussed in Section 3.6.4. Results of analysis performed on water samples collected from two tributaries in the area of the OWMC Preferred Site, Sucker Creek and 9C Creek, are included in Tables K33 to K56. Comments on the creek data can be found in Section 3.6.7.

During the summer low sampling held on 3 September 1986, river sediments were collected at two sites on the Welland River, Wellandport Bridge and Pearson Bridge. Sediment quality data are presented in Tables K26 through K31 and discussed in Section 3.6.5.

On 28 February, 1986 snow samples were collected from various locations on the Preferred Site. The samples were composited and analysis performed on the composite. Table K32 contains the snow quality data which are discussed in Section 3.6.6.

Samples were collected for dioxin analysis on 3 September 1986. Both a water and a sediment sample were collected at Pearson Bridge. Results of the dioxin analysis are presented in Table K57. A commentary of these results can be found in Section 3.6.8.

It should be noted that in Tables K2 through K57 the date is shown as year, month and day (e.g. 14 February, 1986 is shown as 19860214). In the tables the following abbreviations are used:

n/a - data not available;
TR - trace quantity detected.

TABLE K1

GLOSSARY FOR WATER QUALITY TABLES

GENERAL CHEMISTRY

T	Temperature in °C
pH	log (hydronium ion activity)
DO	Dissolved Oxygen
COND	Conductivity in umhos/cm
TDS	Total dissolved solids
TURB	Turbidity in nephelometric turbidity units
ALK	Alkalinity as $CaCO_3$
TOC	Total organic carbon as C
Na	Sodium
K	Potassium
Mg	Magnesium
Ca	Calcium
F	Fluoride
Cl	Chloride
Br	Bromide
NO_3	Nitrate as NO_3
SO_4	Sulfate as SO_4
PO_4	Phosphate as PO_4

NUTRIENTS

NH_3	Ammonia as N
TKN	Total kjeldahl nitrogen
TOTP	Total phosphorus
NO_3	Nitrate as No_3
NO_2	Nitrite as NO_2
BOD	Biochemical oxygen demand - 5 day as mg/L oxygen

BACTERIOLOGICAL

TC	Total Coliforms
FC	Fecal Coliforms
FS	Fecal Streptococci
BGND	Background Bacteria

TRACE CONSTITUENTS

As	Arsenic
Cd	Cadmium
Cr	Chromium
CN	Cyanide
Pb	Lead
Hg	Mercury
S	Sulphide
Al	Aluminum
Cu	Copper
Fe	Iron
Mn	Manganese
PHEN	Phenols
Zn	Zinc

PRIORITY ORGANICS-VOLATILES

ACR	acrolein
TRIC	1,1,1-trichloroethane
VCM	vinyl chloride
TCE	trichloroethylene
MEBR	bromoform
14DB	1,4-dichlorobenzene
MEBRCL2	dichlorobromomethane
MECL3	chloroform
PHI	benzene
ACN	acrylonitrile
12DB	1,2-dichlorobenzene
CB	chlorobenzene
13DB	1,3-dichlorobenzene
MEF2CL2	dichlorodifluoromethane
11DCE	1,1-dichloroethylene
13DCP	1,3-dichloropropene
MEBR2CL	dibromochloromethane
OPHIX	o-xylene
MECL	chloromethane
112TCE	1,1,2-trichloroethane
CCL4	carbon tetrachloride
11CLET	1,1-dichloroethane
12DCP	1,2-dichloropropane
PHIME	toluene
12DCE	1,2-dichloroethane
PCE	tetrachloroethylene
PPHIX	p-xylene
ETPHI	ethylbenzene
MEFCL3	trichlorfluoromethane
ETCL	chloroethane
1122TCE	1,1,2,2-tetrachloroethane
BRET	bromoethane
12DCET	1,2-t-dichloroethylene
MPHIX	m-xylene

PRIORITY ORGANICS - ACID EXTRACTABLES (mainly phenol:

PCP	pentachlorophenol
2NP	2-nitrophenol
4NP	4-nitrophenol
24CP	2,4-dichlorophenol
245TCP	2,4,5-trichlorophenol
234TCP	2,3,4-trichlorophenol
PCMC	p-chloro-m-cresol
P	phenol
2345TCP	2,3,4,5-tetrachlorophenol
246TCP	2,4,6-trichlorophenol
2356TCP	2,3,5,6-tetrachlorophenol
24NP	2,4-dinitrophenol
46NC	4,6-dinitro-o-cresol
24MEP	2,4 dimethylphenol
2CP	2-chlorophenol

TABLE K1

GLOSSARY FOR WATER QUALITY TABLES

(continued)

PRIORITY ORGANICS - Base/Neutral Extractables

HCCP	hexachlorocyclopentadiene
ISOP	isophorone
NP	nitrobenzene
BCIPE	bis(2-chloroisopropyl)ether
DMPH	dimethyl phthalate
NPHTH	naphthalene
BCEME	bis(2-chloroethoxy)methane
HCBD	hexachlorobutadiene
4CPPE	4-chlorophenyl phenyl ether
DBPH	di-n-butylphthalate
26NT	2,6-dinitrotoluene
BZID	benzidine
2CNP	2-chloronaphthalene
BBP	butyl benzyl phthalate
NPA	N-nitroso-n-propylamine
DOP	di-n-octylphthalate
BCE	bis(2-chloroethyl)ether
236TCT	2,3,6-trichlorotoluene
DEP	diethyl phthalate
12PH	1,2-diphenylhydrazine
33CBZID	3,3'-dichlorobenzidine
NMA	N-nitrosodimethylamine
NPA	N-nitrosodiphenylamine
CVE	2-chloroethyl vinyl ether
BPHI	biphenyl
HCB	hexachlorobenzene
1245TCB	1,2,4,5-tetrachlorobenzene
HCE	hexachloroethane
DPE	diphenylether
1234TCB	1,2,3,4-tetrachlorobenzene
1235TCB	1,2,3,5-tetrachlorobenzene
123TCB	1,2,3-trichlorobenzene
124TCB	1,2,4-trichlorobenzene
BPE	4-bromophenyl phenyl ether
24NT	2,4-dinitrotoluene
BCMEE	bis(chloromethyl)ether
245TCT	2,4,5-trichlorotoluene
135TCB	1,3,5-trichlorobenzene
D2EP	bis(2-ethylhexyl)phthalate
PCPHI	pentachlorobenzene

PRIORITY ORGANICS PAH, PCB

ACNY	acenapthylene
ACN	acenapthene
9HF	9H fluorene
PHEN	phenanthrene
ANTH	anthracene
FLUOR	fluoranthene
PYR	pyrene
CHR	chrysene
BAA	benzo(A)anthracene
BAP	benzo(A)pyrene
BKFA	benzo(K)fluoranthene
BBFA	benzo(B)fluoranthene
BAHA	dibenzo(AH)anthracene
BPERY	benzo(GHI)perylene
INDOP	indeno(123-CD)pyrene
MEPHEN	methyl phenanthrene
PCB	polychlorinated biphenyls

PRIORITY ORGANICS - PESTICIDES AND HERBICIDES

BBHC	beta-BHC
CCD	gamma-chlordane
ACD	alpha-chlordane
ALD	aldrin
MIR	mirex
ENDOS	endosulfan sulfate
END	endrin
MECH	methoxychlor
DIEL	dieldrin
ABHC	alpha-BHC
AENDOS	a-endosulfan-alpha
LIND	gamma-BHC(lindane)
ENDA	endrin aldehyde
TOX	toxaphene
DBHC	delta-BHC
DDD	p,p-DDD
OPDDT	o,p-DDT
OXYC	oxychlordane
HEPTE	heptachlor epoxide
HEPT	heptachlor
PPDDT	p,p-DDT
DDE	p,p-DDE
BENDOS	b-endosulfan-beta
245T	2,4,5-T
24D	2,4-D
SILV	silvex
DIAZ	diazinon
MEPARA	methylparathion
PARA	parathion
ALA	alachlor
ATR	atrazine

TABLE K2

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: GENERAL CHEMISTRY

ALL DATA IN MG/L EXCEPT AS NOTED IN TABLE K1

	FIELD DATA				COLLECTIVE DESCRIPTORS				MAJOR CATIONS				MAJOR ANIONS					
DATE	T	pH	DO	COND	TDS	TURB	ALK	TOC	Na	K	Mg	Ca	F	Cl	Br	NO3	SO4	PO4
19860214	1.0	7.06	7.9	388	291	40	71.0	11.0	15.4	4.1	12.2	35.8	0.099	26.2	<0.05	7.75	60.6	<0.1
19860402	13.5	7.32	8.1	330	328	153	93.3	13.0	17.3	8.2	16.0	40.0	0.196	29.4	<0.05	5.29	73.8	<0.1
19860903	23.2	7.75	6.8	436	374	67	98.0	18.5	14.4	5.4	15.7	53.3	0.218	28.3	0.18	2.93	76.1	<1.0
19861111	6.1	8.15	10.4	496	318	43	114.0	9.5	18.6	5.1	17.0	49.8	0.222	31.1	<0.05	0.41	70.8	<0.1

TABLE K3

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: GENERAL CHEMISTRY

ALL DATA IN MG/L EXCEPT AS NOTED IN TABLE K1

	FIELD DATA				COLLECTIVE DESCRIPTORS				MAJOR CATIONS				MAJOR ANIONS					
DATE	T	pH	DO	COND	TDS	TURB	ALK	TOC	Na	K	Mg	Ca	F	Cl	Br	NO3	SO4	PO4
19860214	0.3	6.92	8.0	391	1170	35	64.0	8.0	15.1	4.3	10.8	30.5	0.105	26.2	<0.05	7.48	52.5	<0.1
19860402	13.5	7.24	8.9	382	308	105	87.6	11.0	15.5	6.6	13.3	34.8	0.196	27.3	<0.05	5.59	62.7	<0.1
19860903	22.0	8.14	8.5	572	458	33	124.0	9.5	23.4	5.9	19.9	64.2	0.310	49.8	0.28	1.03	108	<1.0
19861111	5.5	7.92	9.8	472	298	41	101.0	20.0	15.3	6.9	17.4	47.6	0.220	25 8	<0.05	0.61	66.6	<0.1

TABLE K4

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: NUTRIENTS & BACTERIOLOGICAL

NUTRIENT DATA IN MG/L, BACTERIOLOGICAL IN COUNTS/100 mL
EXCEPT AS NOTED IN TABLE K1

	NUTRIENTS						BACTERIOLOGICAL			
DATE	NH3	TKN	TOTP	NO3	NO2	BOD	TC	FC	FS	BGND
19860214	0.20	0.97	0.81	7.75	<0.02	2.3	2100	68	48	6900
19860402	0.07	1.61	0.35	5.29	<0.02	11	10000	136	30	19700
19860903	0.29	1.04	0.24	2.93	<0.20	7	30000	13300	87	16000
19861111	0.06	0.80	0.18	0.41	<0.02	8	1100	420	630	354500

TABLE K5

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: NUTRIENTS & BACTERIOLOGICAL

NUTRIENT DATA IN MG/L, BACTERIOLOGICAL IN COUNTS/100 mL
EXCEPT AS NOTED IN TABLE K1

	NUTRIENTS						BACTERIOLOGICAL			
DATE	NH3	TKN	TOTP	NO3	NO2	BOD	TC	FC	FS	BGND
19860214	0.35	1.08	0.15	7.48	<0.02	2.8	8850	82	104	14450
19860402	0.11	1.42	0.27	5.59	<0.02	29	18000	16	2	24700
19860903	0.32	0.80	0.16	1.03	<0.20	5	5000	2100	29	2600
19861111	0.05	0.97	0.20	0.61	<0.02	2	830	180	80	127000

TABLE K6

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: TRACE CONSTITUENTS

ALL DATA IN UG/L

	HEALTH							AESTHETIC					
DATE	As	Cd	Cr	CN	Pb	Hg	S	Al	Cu	Fe	Mn	PHEN	Zn
19860214	<1	<1	<1	7	<5	<0.05	19	1280	7.7	899	101	<1	12
19860402	1	<1	7	<4	2	<0.05	3	15700	8	8280	159	<1	40
19860903	<1	<1	<1	<4	<1	<0.05	<1	558	4	1060	215	<1	12
19861111	1	<1	<1	<4	<1	<0.05	2	1790	8	2740	78	<1	130

TABLE K7

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: TRACE CONSTITUENTS

ALL DATA IN UG/L

	HEALTH							AESTHETIC					
DATE	As	Cd	Cr	CN	Pb	Hg	S	Al	Cu	Fe	Mn	PHEN	Zn
19860214	<1	<1	<1	11	<5	<0.05	34	1220	7.1	926	85	<1	19
19860402	1	<1	<1	6	2	<0.05	1	11100	10	5860	118	<1	30
19860903	<1	<1	<1	<4	<1	<0.05	<1	324	4	620	93	<1	7
19861111	1	<1	<1	<4	<1	<0.05	2	2030	3	3080	84	<1	238

TABLE K8

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACR	TRIC	VCM	TCE	MEBR	14DB	MEBRCL2	MECL3	PHI	ACN	12DB	CB	MEF2CL2	11DCE	13DCP
19860214	<5	<2	<5	<2	<2	n/a	<2	<2	<2	<5	n/a	<2	<5	<2	<2
19860402	<5	<2	<5	<2	<2	n/a	<2	<2	<2	<5	n/a	<2	<5	<2	<2
19860903	n/a	<1	<2	<1	<1	<1	<1	<1	<0.5	n/a	<1	<.5	<2	<1	n/a
19861111	<10	<1	<2	<1	<1	<1	<1	TR	TR	<10	<1	<0.5	<2	<1	<1

TABLE K9

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	OPHIX	MECL	112TCE	CCL4	12DCP	PHIME	12DCE	PCE	PPHIX	ETPHI	MEPCL3	1122TCE	BRET	12DCET	MPHIX
19860214	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19860402	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19860903	<0.5	<2	<1	<1	<1	TR	<1	<1	TR	<0.5	<2	<1	n/a	<1	TR
19861111	<0.5	<2	<1	<1	<1	TR	<1	<1	<0.5	<0.5	<2	<2	<5	<1	<0.5

TABLE K10

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACR	TRIC	VCM	TCE	MEBR	14DB	MEBRCL2	MECL3	PHI	ACN	12DB	CB	MEF2CL2	11DCE	13DCP
19860214	<5	<2	<5	<2	<2	n/a	<2	<2	<2	<5	n/a	<2	<5	<2	<2
19860402	<5	<2	<5	<2	<2	n/a	<2	<2	<2	<5	n/a	<2	<5	<2	<2
19860903	n/a	<1	<2	<1	<1	<1	<1	<1	<0.5	n/a	<1	<0.5	<2	<1	n/a
19861111	<10	<1	<2	<1	<1	<1	<1	<1	TR	<10	<1	<0.5	<2	<1	<1

TABLE K11

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	OPHIX	MECL	112TCE	CCL4	12DCP	PHIME	12DCE	PCE	PPHIX	ETPHI	MEFCL3	1122TCE	BRET	12DCET	MPHIX
19860214	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19860402	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19860903	<0.5	<2	<1	<1	<1	TR	<1	<1	TR	<0.5	<2	<1	n/a	<1	TR
19861111	<0.5	<2	<1	<1	<1	<0.5	<1	<1	<0.5	<0.5	<2	<2	<5	<1	<0.5

TABLE K12

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - ACID EXTRACTABLES (MAINLY PHENOLS)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	PCP	2NP	4NP	24CP	245TCP	234TCP	PCMC	P	2345TCP	246TCP	2356TCP	24NP	46NC	24MEP	2CP
19860214	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860903	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19861111	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2

TABLE K13

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - ACID EXTRACTABLES (MAINLY PHENOLS)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	PCP	2NP	4NP	24CP	245TCP	234TCP	PCMC	P	2345TCP	246TCP	2356TCP	24NP	46NC	24MEP	2CP
19860214	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860402	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860903	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19861111	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2

TABLE K14

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCCP	ISOP	NP	BCIPE	DMPH	NPHTH	BCEME	HCBD	4CPPE	DBPH	26NT	BZID	2CNP
19860214	<1	<1	<1	<1	<2	<1	<2	<1	<1	3.0	<2	<5	<1
19860903	<1	<1	<1	<1	<2	<1	<2	<1	<1	1.3	<2	<5	<1
19861111	<1	<1	<1	<1	<2	<1	<2	<1	<1	<1	<2	<5	<1

TABLE K15

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBP	NPA	DOP	BCE	236TCT	DEP	12PH	33CBZID	NMA	NPA	CVE	BPHI	HCB	1245TCB
19860214	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	TR	n/a
19860903	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	<1	n/a
19861111	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	<1	n/a

TABLE K16

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCE	DPE	1234TCB	1235TCB	123TCB	124TCB	BPE	24NT	245TCT	BCMEE	135TCB	D2EP	PCPHI
19860214	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	10.8	n/a
19860903	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	7.5	n/a
19861111	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	11.4	n/a

TABLE K17

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCCP	ISOP	NP	BCIPE	DMPH	NPHTH	BCEME	HCBD	4CPPE	DBPH	26NT	BZID	2CNP
19860214	<1	<1	<1	<1	<2	<1	<2	<1	<1	3.3	<2	<5	<1
19860402	<1	<1	<1	<1	<2	<1	<2	<1	<1	<1	<2	<5	<1
19860903	<1	<1	<1	<1	<2	<1	<2	<1	<1	2.3	<2	<5	<1
19861111	<1	<1	<1	<1	<2	<1	<2	<1	<1	1.7	<2	<5	<1

TABLE K18

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBP	NPA	DOP	BCE	236TCT	DEP	12PH	33CBZID	NMA	NPA	CVE	BPHI	HCB	1245TCB
19860214	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	TR	n/a
19860402	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	<1	n/a
19860903	<2	<3	<2	<1	n/a	8.0	<5	<5	n/a	<4	n/a	n/a	<1	n/a
19861111	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	TR	n/a

TABLE K19

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCE	DPE	1234TCB	1235TCB	123TCB	124TCB	BPE	24NT	245TCT	BCMEE	135TCB	D2EP	PCPHI
19860214	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	11.1	n/a
19860402	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	<2	n/a
19860903	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	270.3	n/a
19861111	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	30.1	n/a

TABLE K20

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - PAH,PCB

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACNY	ACN	9HF	PHEN	ANTH	FLUOR	PYR	CHR	BAA	BAP	BKFA	BBFA	BAHA	BPERY	INDOP	MEPHEN	PCB
19860214	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860903	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19861111	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100

TABLE K21

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - PAH,PCB

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACNY	ACN	9HF	PHEN	ANTH	FLUOR	PYR	CHR	BAA	BAP	BKFA	BBFA	BAHA	BPERY	INDOP	MEPHEN	PCB
19860214	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860402	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860903	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19861111	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100

TABLE K22

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBHC	CCD	ACD	ALD	MIR	ENDOS	END	MECH	DIEL	ABHC	AENDOS	LIND	ENDA	TOX	DBHC
19860214	<10	<25	<25	TR	<50	n/a	<20	<20	<45	<10	<25	<10	n/a	n/a	n/a
19860903	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a
19861111	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a

TABLE K23

WELLAND RIVER WATER QUALITY

SITE STATION:4A - WELLANDPORT BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES (CONTINUED)

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	DDD	OPDDT	DDE	OXYC	HEPTE	HEPT	PPDDT	BENDOS	T245	D24	SILV	DIAZ	MEPARA	PARA	ALA	ATR
19860214	<20	n/a	<20	<25	<20	<15	<20	<25	n/a	n/a	n/a	<400	<200	n/a	n/a	<200
19860903	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	5000
19861111	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	TR

TABLE K24

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBHC	CCD	ACD	ALD	MIR	ENDOS	END	MECH	DIEL	ABHC	AENDOS	LIND	ENDA	TOX	DBHC
19860214	<10	<25	<25	TR	<50	n/a	<20	<20	<45	<10	<25	<10	n/a	n/a	n/a
19860402	<10	<25	<25	<10	<50	n/a	<20	<20	<45	<10	<25	<10	n/a	n/a	n/a
19860903	<10	<25	<25	<10	<50	n/a	<20	<20	<45	<10	<25	<10	n/a	n/a	n/a
19861111	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a

TABLE K25

WELLAND RIVER WATER QUALITY

SITE STATION:4B - PEARSON BRIDGE

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES (CONTINUED)

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	DDD	OPDDT	DDE	OXYC	HEPTE	HEPT	PPDDT	BENDOS	T245	D24	SILV	DIAZ	MEPARA	PARA	ALA	ATR
19860214	<20	n/a	<20	<25	<20	<15	<20	<25	n/a	n/a	n/a	<400	<200	n/a	n/a	<200
19860402	<20	n/a	<20	<25	<20	<15	<20	<25	n/a	n/a	n/a	<400	<200	n/a	n/a	<200
19860903	<20	n/a	<20	<25	<20	<15	<20	<25	n/a	n/a	n/a	<400	<200	n/a	n/a	<200
19861111	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	TR

TABLE K26

1986 SEDIMENT QUALITY

SAMPLING DATE: 3 SEPTEMBER 1986

PARAMETER GROUPING: GENERAL CHEMISTRY AND NUTRIENTS

ALL DATA IN MG/KG

	MAJOR CATIONS				MAJOR ANIONS						NUTRIENTS	
SITE	Na	K	Mg	Ca	F	Cl	Br	NO3	SO4	PO4	NH3	TKN
W'PORT BR	344	10400	14350	12100	4.09	102	<0.5	<0.5	339	<1	427	2500
PEARSON BR	330	10100	11300	9480	3.92	123	<0.5	<0.5	238	<1	616	4060

TABLE K27

1986 SEDIMENT QUALITY

SAMPLING DATE: 3 SEPTEMBER 1986

PARAMETER GROUPING: TRACE CONSTITUENTS

ALL DATA IN MG/KG EXCEPT AS NOTED

SITE	As	Cd	Cr	CN	Pb	Hg	S(%)	Al	Cu	Fe	Mn	PHEN	Zn
W'PORT BR	6.22	<0.5	9.4	0.2	54	n/a	0.162	43500	32.6	41900	800	n/a	138
PEARSON BR	7.75	<0.5	12.6	0.2	20	n/a	0.549	40800	28.7	35800	530	n/a	106

TABLE K28

1986 SEDIMENT QUALITY

SAMPLING DATE: 3 SEPTEMBER 1986

PARAMETER GROUPING: PRIORITY ORGANICS - ACID EXTRACTABLES (MAINLY PHENOLS)

ALL DATA IN MG/KG,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

SITE	PCP	2NP	4NP	24CP	245TCP	234TCP	PCMC	P	2345TCP	246TCP	2356TCP	24NP	46NC	24MEP	2CP
W'PORT BR	<0.2	<0.5	<0.5	<0.2	n/a	n/a	<0.5	<0.3	n/a	<0.2	n/a	<0.3	<0.5	<0.2	<0.2
PEARSON BR	<0.2	<0.5	<0.5	<0.2	n/a	n/a	<0.5	<0.3	n/a	<0.2	n/a	<0.3	<0.5	<0.2	<0.2

TABLE K29

1986 SEDIMENT QUALITY

SAMPLING DATE: 3 SEPTEMBER 1986

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES

ALL DATA IN MG/KG,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

SITE	HCCP	ISOP	NP	BCIPE	DMPH	NPHTH	BCEME	HCBD	4CPPE	DBPH	26NT	BZID	2CNP
W'PORT BR	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.2	<0.1	<0.1	<0.1	<0.2	<0.5	<0.1
PEARSON BR	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.2	<0.1	<0.1	<0.1	<0.2	<0.5	<0.1

SITE	BBP	NPA	DOP	BCE	236TCT	DEP	12PH	33CBZID	NMA	NPA	CVE	BPHI	HCB	1245TCB
W'PORT BR	<0.2	<0.3	<0.2	<0.1	n/a	<0.2	<0.5	<0.5	n/a	<0.4	n/a	n/a	<1	n/a
PEARSON BR	<0.2	<0.3	<0.2	<0.1	n/a	<0.2	<0.5	<0.5	n/a	<0.4	n/a	n/a	<1	n/a

SITE	HCE	DPE	1234TCB	1235TCB	123TCB	124TCB	BPE	24NT	245TCT	BCMEE	135TCB	D2EP	PCPHI
W'PORT BR	<0.1	n/a	n/a	n/a	n/a	<0.1	<0.1	<0.2	n/a	n/a	n/a	2.526	n/a
PEARSON BR	<0.1	n/a	n/a	n/a	n/a	<0.1	<0.1	<0.2	n/a	n/a	n/a	1.298	n/a

TABLE K30

1986 SEDIMENT QUALITY

SAMPLING DATE: 3 SEPTEMBER 1986

PARAMETER GROUPING: PRIORITY ORGANICS - PAH,PCB

ALL DATA IN MG/KG,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

SITE	ACNY	ACN	9HF	PHEN	ANTH	FLUOR	PYR	CHR	BAA	BAP	BKFA	BBFA	BAHA	BPERY	INDOP	MEPHEN	PCB
W'PORT BR	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	n/a	<30
PEARSON BR	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	n/a	<30

TABLE K31

1986 SEDIMENT QUALITY

SAMPLING DATE: 3 SEPTEMBER 1986

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES

ALL DATA IN UG/KG,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

SITE	BBHC	CCD	ACD	ALD	MIR	ENDOS	END	MECH	DIEL	ABHC	AENDOS	LIND	ENDA	TOX	DBHC
W'PORT BR	<1	<3	<3	<1	<2	n/a	<1	<3	<1	<1	<2	<1	n/a	n/a	n/a
PEARSON BR	<1	<3	<3	<1	<2	n/a	<1	<3	<1	<1	<2	<1	n/a	n/a	n/a

SITE	DDD	OPDDT	DDE	OXYC	HEPTE	HEPT	PPDDT	BENDOS	T245	D24	SILV	DIAZ	MEPARA	PARA	ALA	ATR
W'PORT BR	<2	n/a	<2	<3	<1.5	<1	<2	<2	<0.5	<0.05	<0.5	<2	<1	n/a	n/a	<1
PEARSON BR	<2	n/a	<2	<3	<1.5	<1	<2	<2	<0.5	<0.05	<0.5	<2	<1	n/a	n/a	<1

TABLE K32

1986 SNOW QUALITY

ALL DATA IN MG/L EXCEPT TRACE CONSTITUENTS IN UG/L

	COLLECTIVE DESCRIPTORS				MAJOR CATIONS				MAJOR ANIONS					
DATE	TDS	TURB	ALK	TOC	Na	K	Mg	Ca	F	Cl	Br	NO3	SO4	PO4
19860228	24	3	3.4	0.5	0.850	<0.1	0.543	1.68	<0.005	1.41	<0.05	3.60	2.35	<0.1

	TRACE CONSTITUENTS												
DATE	As	Cd	Cr	CN	Pb	Hg	S	Al	Cu	Fe	Mn	PHEN	Zn
19860228	<1	<1	<1	<4	16	<0.05	10	37	2.3	41	15	<1	15

	NUTRIENTS				
DATE	NH3	TKN	TOTP	NO3	NO2
19860228	0.44	0.54	0.02	3.60	<0.02

TABLE K33

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: GENERAL CHEMISTRY

ALL DATA IN MG/L EXCEPT AS NOTED IN TABLE K1

	FIELD DATA				COLLECTIVE DESCRIPTORS				MAJOR CATIONS				MAJOR ANIONS					
DATE	T	pH	DO	COND	TDS	TURB	ALK	TOC	Na	K	Mg	Ca	F	Cl	Br	NO3	SO4	PO4
19860214	1.0	6.96	11.8	332	290	71	75.0	15.0	8.9	4.7	11.0	33.7	0.111	12.6	<0.05	4.72	46.6	<0.1
19860311	1.1	n/a	11.8	114	150	128	28.0	9.8	5.3	9.6	6.04	11.5	0.141	5.4	<0.05	6.40	11.7	<0.1
19860313	0.9	6.63	11.2	165	401	327	36.0	16.0	11.0	19.3	12.9	16.4	0.161	15.3	<0.05	9.20	21.8	<0.1
19860314	1.8	6.51	10.6	181	254	116	35.0	16.5	5.5	8.6	6.56	15.8	0.161	12.2	<0.05	7.69	20.0	<0.1
19860402	12.7	7.42	12.8	332	271	54	82.2	25.0	9.9	5.0	10.8	28.6	0.187	17.3	<0.05	1.74	41.9	<0.1
19860429	14.1	7.96	13.0	285	246	40	18.4	26.0	8.7	5.7	10.9	34.9	0.209	13.0	<0.05	1.50	33.6	0.3
19860807a	20.?	7.17	6.6	651	580	30	102.0	12.3	23.0	7.3	24.4	77.1	0.223	61.4	<0.05	7.51	149	<1.0
19860807b	21.1	7.62	8.0	583	514	55	84.0	14.5	16.8	6.3	22.5	68.2	0.217	45.2	<0.05	12.5	126	<1.0
19860807c	24.2	7.24	7.2	634	600	40	98.0	20.0	24.4	11.7	22.9	71.2	0.224	54.5	<0.05	18.3	147	<1.0
19861008	11.8	7.33	7.0	380	246	50	94.0	26.0	9.0	10.9	12.7	39.6	0.219	15.4	<0.05	<0.05	47.5	<0.1
19861111	4.2	6.75	10.2	518	344	40	115.0	21.0	11.4	10.0	16.2	48.7	0.220	32.5	<0.05	3.56	65.5	<0.1

TABLE K34

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: GENERAL CHEMISTRY

ALL DATA IN MG/L EXCEPT AS NOTED IN TABLE K1

	FIELD DATA				COLLECTIVE DESCRIPTORS				MAJOR CATIONS				MAJOR ANIONS					
DATE	T	pH	DO	COND	TDS	TURB	ALK	TOC	Na	K	Mg	Ca	F	Cl	Br	NO3	SO4	PO4
19860429	14.5	7.83	13.4	801	656	23	150.0	23.0	29.0	4.0	46.6	65.5	0.454	22.6	<0.05	31.4	258	<0.1
19860807	19.8	7.27	4.0	872	740	63	94.0	12.0	55.5	10.1	30.2	79.4	0.444	103	<0.05	31.1	178	<1.0

TABLE K35

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: NUTRIENTS & BACTERIOLOGICAL

NUTRIENT DATA IN MG/L, BACTERIOLOGICAL IN COUNTS/100 mL
EXCEPT AS NOTED IN TABLE K1

	NUTRIENTS						BACTERIOLOGICAL			
DATE	NH3	TKN	TOTP	NO3	NO2	BOD	TC	FC	FS	BGND
19860214	0.50	1.59	0.86	4.72	<0.02	4.1	2800	114	40	7200
19860311	0.71	2.09	0.49	6.40	<0.02	166	98000	126	950	255000
19860313	0.60	2.53	0.91	9.20	<0.02	170	630000	920	3200	720000
19860314	0.60	1.88	0.43	7.69	<0.02	223	450000	740	2200	390000
19860402	<0.02	1.54	0.45	1.74	<0.02	15	5000	56	29	11600
19860429	0.03	2.36	0.64	1.50	<0.20	212	12000	230	136	6800
19860807a	0.05	0.94	0.05	7.51	<0.20	7	1100000	252000	41000	400000
19860807b	0.05	1.16	0.11	12.5	<0.20	5	1280000	470000	67000	720000
19860807c	0.10	2.09	0.22	18.3	<0.20	9	1000000	620000	76000	770000
19861008	0.06	1.25	0.49	<0.05	<0.02	8	166000	2200	1440	24200
19861111	0.11	1.26	0.33	3.56	<0.02	5	1240	710	2360	1110000

TABLE K36

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: NUTRIENTS & BACTERIOLOGICAL

NUTRIENT DATA IN MG/L, BACTERIOLOGICAL IN COUNTS/100 mL
EXCEPT AS NOTED IN TABLE K1

	NUTRIENTS						BACTERIOLOGICAL			
DATE	NH3	TKN	TOTP	NO3	NO2	BOD	TC	FC	FS	BGND
19860429	2.64	5.00	0.65	31.4	1.40	188	8000	58	80	3700
19860807	0.10	1.00	0.31	31.1	<0.20	8	1600000	640000	55000	610000

TABLE K37

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: TRACE CONSTITUENTS

ALL DATA IN UG/L

	HEALTH							AESTHETIC					
DATE	As	Cd	Cr	CN	Pb	Hg	S	Al	Cu	Fe	Mn	PHEN	Zn
19860214	<1	<1	1	7	<5	<0.05	38	2000	5.2	1350	85	<1	19
19860311	1	<1	<2	<4	5	<0.05	14	21700	16	10300	262	<1	60
19860313	3	<1	<2	<4	<1	<0.05	14	52300	27	26300	286	4	105
19860314	1	<1	16	<4	5	<0.05	14	16400	16	9540	205	4	60
19860402	1	<1	12	7	2	<0.05	2	5420	7	3100	139	<1	30
19860429	3	4	<1	18	3	<0.05	<1	702	6	2010	95	<1	20
19860807a	<1	3	<1	10	<1	<0.05	<1	273	5	532	173	<1	10
19860807b	<1	<1	<1	10	<1	<0.05	<1	478	4	609	85	<1	9
19860807c	<1	<1	<1	13	<1	<0.05	<1	573	10	344	56	<1	49
19861008	2	<1	4	<4	<1	<0.05	2	327	15.3	2940	22	<1	34
19861111	1	<1	<1	<4	<1	<0.05	2	945	14	1200	82	<1	172

TABLE K38

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: TRACE CONSTITUENTS

ALL DATA IN UG/L

	HEALTH							AESTHETIC					
DATE	As	Cd	Cr	CN	Pb	Hg	S	Al	Cu	Fe	Mn	PHEN	Zn
19860429	1	<1	<1	35	3	<0.05	<1	212	6	716	347	6	130
19860807	<1	<1	<1	24	<1	<0.05	<1	541	5	713	89	<1	15

TABLE K39

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACR	TRIC	VCM	TCE	MEBR	14DB	MEBRCL2	MECL3	PHI	ACN	12DB	CB	MEF2CL2	11DCE	13DCP
19860214	<5	<2	<5	<2	<2	n/a	<2	9.1	<2	<5	n/a	<2	<5	<2	<2
19860402	<5	<2	<5	<2	<2	n/a	<2	<2	<2	<5	n/a	<2	<5	<2	<2
19861111	<10	<1	<2	<1	<1	<1	<1	TR	TR	<10	<1	<0.5	<2	<1	<1

TABLE K40

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	OPHIX	MECL	112TCE	CCL4	12DCP	PHIME	12DCE	PCE	PPHIX	ETPHI	MEFCL3	1122TCE	BRET	12DCET	MPHIX
19860214	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19860402	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19861111	<0.5	<2	<1	<1	<1	TR	<1	<1	<0.5	<0.5	<2	<2	<5	<1	<0.5

TABLE K41

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACR	TRIC	VCM	TCE	MEBR	14DB	MEBRCL2	MECL3	PHI	ACN	12DB	CB	MEF2CL2	11DCE	13DCP
19860429	<5	<2	<5	<2	<2	n/a	<2	<2	<2	<5	n/a	<2	<5	<2	<2

TABLE K42

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	OPHIX	MECL	112TCE	CCL4	12DCP	PHIME	12DCE	PCE	PPHIX	ETPHI	MEFCL3	1122TCE	BRET	12DCET	MPHIX
19860429	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a

TABLE K43

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - ACID EXTRACTABLES (MAINLY PHENOLS)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	PCP	2NP	4NP	24CP	245TCP	234TCP	PCMC	P	2345TCP	246TCP	2356TCP	24NP	46NC	24MEP	2CP
19860214	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860807a	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860807b	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860807c	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19861111	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2

TABLE K44

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - ACID EXTRACTABLES (MAINLY PHENOLS)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	PCP	2NP	4NP	24CP	245TCP	234TCP	PCMC	P	2345TCP	246TCP	2356TCP	24NP	46NC	24MEP	2CP
19860429	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860807	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2

TABLE K45

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCCP	ISOP	NP	BCIPE	DMPH	NPHTH	BCEME	HCBD	4CPPE	DBPH	26NT	BZID	2CNP
19860214	<1	<1	<1	<1	<2	<1	<2	<1	<1	4.5	<2	<5	<1
19860807a	<1	<1	<1	<1	<2	<1	<2	<1	<1	<1	<2	<5	<1
19860807b	<1	<1	<1	<1	<2	<1	<2	<1	<1	2.3	<2	<5	<1
19860807c	<1	<1	<1	<1	<2	<1	<2	<1	<1	1.9	<2	<5	<1
19861111	<1	<1	<1	<1	<2	<1	<2	<1	<1	1.7	<2	<5	<1

TABLE K46

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBP	NPA	DOP	BCE	236TCT	DEP	12PH	33CBZID	NMA	NPA	CVE	BPHI	HCB	1245TCB
19860214	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	0.031	n/a
19860307a	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	<1	n/a
19860807b	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	<1	n/a
19860807c	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	<1	n/a
19861111	<2	<3	<2	<1	n/a	TR	<5	<5	n/a	<4	n/a	n/a	<1	n/a

TABLE K47

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCE	DPE	1234TCB	1235TCB	123TCB	124TCB	BPE	24NT	245TCT	BCMEE	135TCB	D2EP	PCPHI
19860214	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	14.8	n/a
19860807a	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	10.7	n/a
19860807b	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	17.0	n/a
19860807c	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	16.7	n/a
19861111	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	246.3	n/a

TABLE K48

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCCP	ISOP	NP	BCIPE	DMPH	NPHTH	BCEME	HCBD	4CPPE	DBPH	26NT	BZID	2CNP
19860429	<1	<1	<1	<1	<2	<1	<2	<1	<1	2.8	<2	<5	<1
19860807	<1	<1	<1	<1	<2	<1	<2	<1	<1	4.2	<2	<5	<1

TABLE K49

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBP	NPA	DOP	BCE	236TCT	DEP	12PH	33CBZID	NMA	NPA	CVE	BPHI	HCB	1245TCB
19860429	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	TR	n/a
19860807	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	TR	n/a

TABLE K50

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCE	DPE	1234TCB	1235TCB	123TCB	124TCB	BPE	24NT	245TCT	BCMEE	135TCB	D2EP	PCPHI
19860429	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	9.1	n/a
19860807	<1	n/a	n/a	n/a	n/a	TR	<1	<2	n/a	n/a	n/a	40.4	n/a

TABLE K51

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - PAH,PCB

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACNY	ACN	9HF	PHEN	ANTH	FLUOR	PYR	CHR	BAA	BAP	BKFA	BBFA	BAHA	BPERY	INDOP	MEPHEN	PCB
19860214	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860807a	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860807b	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860807c	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19861111	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100

TABLE K52

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - PAH,PCB

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACNY	ACN	9HF	PHEN	ANTH	FLUOR	PYR	CHR	BAA	BAP	BKFA	BBFA	BAHA	BPERY	INDOP	MEPHEN	PCB
19860429	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860807	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100

TABLE K53

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBHC	CCD	ACD	ALD	MIR	ENDOS	END	MECH	DIEL	ABHC	AENDOS	LIND	ENDA	TOX	DBHC
19860214	11.5	<25	<25	TR	<50	n/a	<20	<20	<45	<10	<25	<10	n/a	n/a	n/a
19860807a	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a
19860807b	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a
19860807c	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a
19861111	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a

TABLE K54

SITE VICINITY WATER QUALITY

SITE STATION:SUCKER CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES (CONTINUED)

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	DDD	OPDDT	DDE	OXYC	HEPTE	HEPT	PPDDT	BENDOS	T245	D24	SILV	DIAZ	MEPARA	PARA	ALA	ATR
19860214	<20	n/a	<20	<25	<20	<15	<20	<25	n/a	n/a	n/a	<400	<200	n/a	n/a	<200
19860807a	<20	n/a	<20	<25	<15	<10	<20	<20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
19860807b	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	10000
19860807c	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	11000
19861111	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	3500

TABLE K55

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBHC	CCD	ACD	ALD	MIR	ENDOS	END	MECH	DIEL	ABHC	AENDOS	LIND	ENDA	TOX	DBHC
19860429	<10	<25	<25	<10	<50	n/a	<20	<20	<45	<10	<25	<10	n/a	n/a	n/a
19860807	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a

TABLE K56

SITE VICINITY WATER QUALITY

SITE STATION:9C CREEK

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES (CONTINUED)

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	DDD	OPDDT	DDE	OXYC	HEPTE	HEPT	PPDDT	BENDOS	T245	D24	SILV	DIAZ	MEPARA	PARA	ALA	ATR
19860429	<20	n/a	<20	<25	<20	<15	<20	<25	n/a	n/a	n/a	<400	<200	n/a	n/a	<200
19860807	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	2000

TABLE K57

RESULTS OF DIOXIN ANALYSIS

SAMPLING LOCATION : WELLAND RIVER AT PEARSON BRIDGE

SAMPLING DATE : 3 SEPTEMBER 1986

WATER DATA IN NG/L; SEDIMENT DATA IN UG/L

LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

	TETRA-CDD	PENTA-CDD	HEXA-CDD	HEPTA-CDD	OCTA-CDD	TETRA-CDF	PENTA-CDF	HEXA-CDF	HEPTA-CDF	OCTA-CDF
WATER	2.0	<0.5	<1.0	<2.0	<2.5	<0.9	<0.5	<1.0	<2.0	<2.5
SEDIMENT	<0.2	<1.0	<1.0	<2.0	<3.0	<2.0	<0.5	<1.0	<2.0	<3.0

CDD = CHLORINATED DIBENZODIOXIN
CDF = CHLORINATED DIBENZOFURAN

APPENDIX L
QA/QC DATA

APPENDIX L
QA/QC DATA

Tables L1 through L16 contain quality assessment/quality control (QA/QC) data for the 1986 sampling programs. The QA/QC program for this study consisted of the analysis of duplicates and field blanks.

On three occasions, 2 April 1986, 3 September 1986 and 11 November, 1986, duplicate sample sets were taken at the Pearson Bridge site. One set was submitted to the primary laboratories:

Barringer Magenta Limited	(BML)	- inorganics
Mann Testing Laboratories	(MAN)	- organics
Standard Biological Laboratory	(SBL)	- bacteriological

The second set was submitted to the QA/QC laboratories:

Ontario Research Foundation	(ORF)	- inorganics and bacteriological
Barringer Magenta Limited	(BML)	- organics

The results of analyses performed on the duplicate samples are included in Tables L1, L2 and L3.

A duplicate was also taken of the sediment sample collected at Pearson Bridge on 3 September 1986. The results of the analyses are included in Table L4.

On a number of occasions field blank samples were also submitted for analysis. The results of the analyses are reported in Tables L5 through L16. In these tables dates are shown as year, month, day.

In Tables L1 through L16 the following abbreviations are used:

n/a - data not available;
TR - trace quantity detected

Less than entries list method detection limit.

A detailed assessment of the water quality, sediment, and field blank QA/QC methodology and results and presented following. A synopsis of these results is shown in Section 3.6.1.

1. WATER QUALITY QA/QC DATA

As discussed in Section 2.3.2.5, the quality of QA/QC data determines the reliability, accuracy and precision of the analysis of unknown samples. The results of the laboratory QA/QC programs are presented below. In Chapter 2, the two types of laboratory QA/QC undertaken by the five laboratories involved in this study were discussed, namely:

- intra-laboratory QA/QC
- inter-laboratory QA/QC

The specific details of each laboratory's QA/QC methods are shown in the Protocol Document (Volume 3).

Intra-laboratory QA/QC results and results of laboratory analysis of known standards, blanks and duplicate unknown samples will not be presented here. These results are rigorously checked by each laboratory prior to releasing any analytical data to Dillon. The laboratories have reviewed these data to ensure that their analytical procedures were operating according to specifications. Any QA/QC results that were found to be anomalous were questioned and the entire analytical run repeated if necessary. These QA/QC reviews of the data are being done routinely for all analyses of OWMC water quality and sediment samples. The

analytical data is not released from the laboratories unless all QA/QC results meet their previously set specifications.

Inter-laboratory QA/QC for this study has involved the analysis of replicate samples for all parameters of interest by two laboratories. All QA/QC samples were taken at the Pearson Bridge sampling location. Replicate QA/QC samples were obtained for water samples during the spring (2 April 1986), the summer low (3 September 1986) and the fall (11 November 1986) sampling events. Replicate QA/QC samples to evaluate sediment quality were also collected at Pearson Bridge on 3 September 1986.

As a further check of analytical data quality, 'blank' samples were collected in the field. This involves the filling of sampling bottles with distilled water taken from the laboratory. The distilled water samples are handled and analyzed in the field and at the lab, in the same way as all others.

The purposes for analyzing field 'blank' samples are twofold: They identify:

- contamination present in the bottles that may impact analytical results for unknown samples; and

- airborne contamination (such as dustfall) that again may get into surface water on the day of sampling and impact the unknown results.

The assessment of field blank data collected for all of the 1986 sampling events is also presented in this section.

Inter-laboratory QA/QC results can be evaluated in a number of ways. In all cases, the object of this evaluation is to determine whether the analytical results from the two laboratories are the same statistically. This similarity in duplicate results,

indicates that probability that the results of 'unknown' analyses conducted by the primary laboratory are a reliable and a true estimate of water quality on the day of sampling.

At the time of reporting three QA/QC duplicate checks of water quality results have been completed. As such, there is insufficient data to conduct a statistical assessment of the differences between the duplicates analyses carried out by the two labs. Inter-laboratory results that varied greatly were flagged, the methods used were investigated and where possible the analyses repeated. It is not always possible to repeat analyses. Some constituents in water, such as bacteria and phenol, are very fragile and are lost quickly from water samples. Therefore, repeat analysis of this kind of sample would not give useful information. In these instances, the anomaly was flagged and investigated in further QA/QC testing with fresh samples.

The inter-laboratory results have been evaluated following, and in some instances, sampling or analysis procedures have been modified on this basis.

2. WATER QUALITY QA/QC DATA ASSESSMENT

Comparison of the differences in analyses of duplicate samples by two laboratories indicate that there is close agreement (little difference) between results for the majority of parameters analyzed. All priority organic and trace metals analyzed were found to be in close agreement between the two labs checked. See Tables L1-L3. This confirms that the analytical results produced by the primary laboratories are reliable estimates of actual water quality.

There were three analytical parameters, only, out of the 178 analyzed, where QA/QC comparison indicated large, order of magnitude differences in results between the two labs. These are:

- bacteria analysis
- biochemical oxygen demand (BOD) on 2 April, 1986 only
- phenols.

All three of these constituents are very fragile and, as such, sample reanalysis is of little value. In all three cases the study team investigated the reason for the differences found and implemented corrective measures, where available, to ensure the reliability of the 'unknown' results.

BACTERIA

Bacteria levels in water are determined by physically counting bacterial colonies under a microscope. The analytical (counting) procedure is strongly impacted by the type and quality of the media (growth material) that is used to culture the bacterial growth (Taylor, J.K., 1985). Because of this, bacterial analytical results are more variable than chemical analyses from time to time within and between labs. These differences are shown in the bacterial analyses conducted by SBL and ORF. Both labs follow acceptable protocols (Taylor, J.K. 1985). The laboratories have indicated from their experience that there is no concern in the random variability found, see Tables L1, L2, L3. Dillon will continue to closely check the bacterial analysis from both laboratories.

BOD

BOD was found on 2 April, 1986 to be quite high by SBL and low by ORF. One possible reason for this has been put forward by ORF. Prior to May, BOD samples were being preserved, at laboratory request, with thiosulphate. ORF raised concern that thiosulphate oxidizes, elevating the BOD of the water. This would cause elevated, unrepresentative BOD results. As a result, ORF analyzed an unpreserved sample while SBL analyzed one that was preserved. The low results found by ORF, compared with SBL, may give credence to their concern. The methods for analyzing and

sampling BOD was altered as a result of the 2 April OA/OC check. Both laboratories have been receiving BOD samples unpreserved since that time. The 3 September and 11 November OA/QC checks on BOD show very comparable results between the two labs. This indicates that the change in preservation protocol was necessary and worthwhile. The BOD data from SBL analyzed before May has been flagged, accordingly, as anomalous.

PHENOLICS

Phenolics have consistently been found in elevated levels by ORF as compared with Barringer (approximately 10 times higher). There is no clear explanation for this. The analytical methods and protocols used by both laboratories have been carefully reviewed and have been found by Dillon to be comparable and meet MOE analytical requirements (MOE, 1987). No dilution or calculation errors can be identified by either laboratory. Dillon will continue to scrutinize the inter-lab phenol analysis to determine the source of these anomalous results. As phenols are fragile, the samples could not be reanalyzed. Historical data from the MOE has indicated phenol levels in the same order of magnitude as BMLs. As well, no phenolic compounds have been identified in the priority organics analysis undertaken in this study. Therefore the ORF value may be anomalous.

In general, the water quality results found by the different laboratories are in close agreement. Great concern is not warranted over the validity of bacterial and phenol analyses based on only three QA/QC comparisons. However, these analyses will be closely scrutinized in future.

3. SEDIMENT QUALITY QA/QC DATA ASSESSMENT

Sediments are analyzed by either taking the entire sediment sample (both liquid and solid), extracting the contaminants from it and then analyzing or by drying the sediment to remove the water, then

extracting and analyzing the contaminants from the dried solid. The two laboratories conducting sediment analysis for the inorganics parameters each used a different method. BML dried the sample and determined contaminant levels for the dried sample only. ORF analyzed the entire sampling. Both of these techniques are commonly used and are considered valid by the Dillon study team. The two techniques are also comparable although small variability in analytical data does arise because of the difference in technique.

One sediment QA/QC comparison was carried out on 3 September, 1986. The results from the different labs are generally in close agreement (see Table L4). Some variation in sulphate, for example, could be due to the differences in analytical technique or slight variation in the quality of one replicate sample compared to the other. Metals levels, particularly sodium, potassium and aluminum were reported lower by BML than by ORF. This is due to the extraction method used on the dry analysis to remove contaminant levels from the sediment. Analysis of a sample containing known contaminant levels, extracted in exactly the same manner as the OWMC samples, indicated levels of metals consistently lower than those certified by the National Bureau of Standards for the known sample.

Dillon will continue to review sediment quality data for consistency in 1987 and will ensure that consistent analytical methods are used by BML and ORF.

4. FIELD BLANK DATA ASSESSMENT

As discussed above, field blanks are useful to determine contamination that may be present in sampling bottles and field or laboratory air. The field blank samples analyzed for all 1986 sampling events were valuable for determining this information.

The blank data indicated that very low levels of basic constituents of glass such as magnesium, aluminum and calcium were leaching into the water. The concentrations are of such a low level that they are of no concern to the validity of unknown water quality analyses. The blank data also showed that even deionized water contains low levels of major chemical constituents such as iron.

The field blank data also indicated that small amounts of bacteria are always present either in the bottles or due to sampling methodology. Extreme care is taken to minimize bacterial contamination of bottles during sampling, however, the blank data indicate that bacterial contamination cannot be completely avoided. The levels of bacteria found are extremely low compared to that found in the surface water.

TABLE L1
OWMC - WATER QUALITY
QA/QC DATA - 2 APRIL 1986

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
GENERAL CHEMISTRY (mg/L)				
Collective Descriptors				
pH	7.58	7.75		
Conductivity (umho/cm)	416	399		
Total Dissolved Solids	308	300		
Turbidity (NTU)	105	107		
Alkalinity (as CaCO3)	87.6	88.0		
Total Organic Carbon	11.0	20		
Major Cations				
Sodium	16.2	15		
Potassium	7.1	5.3		
Magnesium	13.5	14.5		
Calcium	35	46		
Major Anions				
Fluoride	0.196	0.16		
Chloride	27.3	26		
Bromide	<0.05	n/a		
Sulphate (as SO_4)	62.7	59		
Phosphate (as PO_4)	<0.1	0.21		
TRACE CONSTITUENTS				
Health (ug/L)				
Arsenic	1	1		
Cadmium	< 1	< 0.1		
Chromium	< 1	< 10		
Cyanide	6	3		
Lead	2	2		
Mercury	< 0.05	< 0.1		
Sulphide	1	0.4		
Aesthetic (mg/L)				
Aluminum	11.7	6.8		
Copper (ug/L)	10	11		
Iron (ug/L)	6.09	6		
Manganese	0.18	0.14		
Phenols (ug/L)	< 1	11		
Zinc	30	n/a		
NUTRIENTS (mg/L)				
Ammonia-N	0.11	< 0.05		
Total Kjeldahl Nitrogen	1.42	1.1		
Total Phosphorus	.27	0.254		
Nitrate (as NO_3)	5.59	4.56		
Nitrite (as NO_2)	<0.02	0.08		
Biochemical Oxygen Demand (mg/L)		3	29	
BACTERIOLOGICAL (/100mL)				
Total Coliform		26000	18000	
Fecal Coliform		10	16	
Fecal Streptococci		550	2	
Background (/mL)		16000	24700	

TABLE L1
OWMC - WATER QUALITY
QA/QC DATA - 2 APRIL 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Volatiles (ug/L)				
acrolein	<5.0			n/a
1,1,1-trichlorethane	<2.0			<1.0
vinyl chloride	<5.0			<2.0
trichlorethylene	<2.0			<1.0
bromoform	<2.0			<1.0
1,4-dichlorobenzene	n/a			<1.0
dichlorobromomethane	<2.0			<1.0
chloroform	<2.0			<1.0
benzene	<2.0			TR
acrylonitrile	<5.0			n/a
1,2-dichlorobenzene	n/a			<1.0
chlorobenzene	<2.0			<0.5
1,3-dichlorobenzene	n/a			<1.0
dichlorodifluorobenzene	<5.0			n/a
1,1-dichloroethylene	<2.0			<1.0
1,3-dichloropropene	<2.0			<1.0
dibromochloromethane	<2.0			<1.0
o-xylene	n/a			<0.5
chloromethane	<5.0			<2.0
1,1,2-trichloroethane	<2.0			<1.0
carbontetrachloride	<2.0			<1.0
1,1-dichloroethane	<2.0			<1.0
1,2-dichloropropane	<2.0			<1.0
toluene	<2.0			<0.5
1,2-dichloroethane	<2.0			<1.0
tetrachloroethylene	<2.0			<1.0
p-xylene	n/a			TR
ethylbenzene	<2.0			<0.5
trichlorofluoromethane	<2.0			<2.0
chloroethane	<5.0			<2.0
1,1,2,2-tetrachloroethane	<2.0			<1.0
bromoethane	n/a			n/a
1,2-t-dichloroethylene	<2.0			<1.0
m-xylene	n/a			TR

TABLE L2
OWMC - WATER QUALITY
QA/QC DATA - 3 SEPTEMBER 1986

PARAMETER	LABORATORY			
	BML	ORF	SRL	MAN
GENERAL CHEMISTRY (mg/L)				
Collective Descriptors				
pH	8.12	7.82		
Conductivity (umho/cm)	571	500		
Total Dissolved Solids	458	389		
Turbidity (NTU)	n/a	47		
Alkalinity (as $CaCO_3$)	124	135		
Total Organic Carbon	n/a	14.0		
Major Cations				
Sodium	23.4	24		
Potassium	5.9	7.6		
Magnesium	19.9	18		
Calcium	64.2	61		
Major Anions				
Fluoride	0.310	0.26		
Chloride	49.8	32.7		
Bromide	0.28	n/a		
Sulphate (as SO_4)	108	78.3		
Phosphate (as PO_4)	< 1.0	0.12		
TRACE CONSTITUENTS				
Health (ug/L)				
Arsenic	< 1	1.4		
Cadmium	< 1	< 2		
Chromium	< 1	< 10		
Cyanide	< 4	< 1		
Lead	< 1	< 20		
Mercury	<0.05	0.07		
Sulphide	< 1	< 20		
Aesthetic (mg/L)				
Aluminum	0.324	2.9		
Copper (ug/L)	4	< 10		
Iron (ug/L)	0.62	2.1		
Manganese	0.093	0.11		
Phenols (ug/L)	< 1	10.8		
Zinc	0.007	0.014		
NUTRIENTS (mg/L)				
Ammonia-N	n/a	0.03		
Total Kjeldahl Nitrogen	n/a	1.3		
Total Phosphorus	0.16	0.18		
Nitrate (as NO_3)	1.03	0.18		
Nitrite (as NO_2)	< 0.20	0.072		
Biochemical Oxygen Demand (mg/L)		2.4	5	
BACTERIOLOGICAL (/100mL)				
Total Coliform		39000	5000	
Fecal Coliform		80	2100	
Fecal Streptococci		20	29	
Background (/mL)		150000	2600	

TABLE L2
OWMC - WATER QUALITY
QA/QC DATA - 3 SEPTEMBER 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Volatiles (ug/L)				
acrolein	<5.0			n/a
1,1,1-trichlorethane	<1.0			<1.0
vinyl chloride	<2.0			<2.0
trichlorethylene	<1.0			<1.0
bromoform	<1.0			<1.0
1,4-dichlorobenzene	<2.0			<1.0
dichlorobromomethane	<1.0			<1.0
chloroform	0.5			<1.0
benzene	<1.0			<0.5
acrylonitrile	<5.0			n/a
1,2-dichlorobenzene	0.5			<1.0
chlorobenzene	<1.0			<0.5
1,3-dichlorobenzene	<2.0			<1.0
1,1-dichloroethylene	<1.0			<1.0
1,3-dichloropropene	<1.0			<1.0
dibromochloromethane	<1.0			<1.0
o-xylene	n/a			<0.5
chloromethane	<2.0			<2.0
1,1,2-trichloroethane	<1.0			<1.0
carbon tetrachloride	<1.0			<1.0
1,1-dichloroethane	<1.0			<1.0
1,2-dichloropropane	<1.0			<1.0
toluene	<1.0			TR
1,2-dichloroethane	<1.0			<1.0
tetrachloroethylene	<1.0			<1.0
p-xylene	n/a			TR
ethylbenzene	<1.0			<0.5
trichlorofluoromethane	<1.0			<2.0
chloroethane	<2.0			<2.0
1,1,2,2-tetrachloroethane	<1.0			<1.0
bromoethane	n/a			n/a
1,2-t-dichloroethylene	<1.0			<1.0
m-xylene	n/a			TR
Acid Extractables (mainly phenols) (ug/L)				
pentachlorophenol	<5.0			<2.0
2-nitrophenol	<5.0			<5.0
4-nitrophenol	<5.0			<5.0
2,4-dichlorophenol	<5.0			<2.0
p-chloro-meta-cresol	n/a			<5.0
phenol	<5.0			<3.0
2,4,6-trichlorophenol	<5.0			<2.0
2,4-dinitrophenol	<10.0			<3.0
4,6-dinitro-o-cresol	n/a			<5.0
2,4-dimethylphenol	<10.0			<2.0
2,-chlorophenol	<5.0			<2.0
Base/Neutral Extractables (ug/L) (plastizers and misc. heavy organics)				
hexachlorocyclopentadiene	n/a			<1.0
isophorone	n/a			<1.0
nitrobenzene	<2.0			<1.0
bis(2-chloroisopropyl)ether	<2.0			<1.0
dimethyl phthalate	<2.0			<2.0

TABLE L2
OWMC - WATER QUALITY
QA/QC DATA - 3 SEPTEMBER 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Base Neutral Extractables (ug/L)				
napthalene	<2.0			<1.0
bis(2-chloroethoxy)methane	<2.0			<2.0
hexachlorobutadiene	<2.0			<1.0
4-chlorophenyl phenyl ether	<2.0			<1.0
di-n-butylphthalate	0.9			2.3
2,6-dinitrotoluene	<2.0			<2.0
benzidine	n/a			<5.0
2-chloronaphthalene	<2.0			<1.0
butyl benzyl phthalate	<2.0			<2.0
N-nitroso-n-propylamine	<20.0			<3.0
di-n-octylphthalate	0.5			<2.0
bis(2-chloroethyl)ether	<2.0			<1.0
diethylphthalate	0.3			8.0
1,2-diphenylhydrazine	n/a			<5.0
3,3'-dichlorobenzidine	<20.0			<5.0
N-nitrosodiphenylamine	n/a			<4.0
hexachlorobenzene	<2.0			<1.0
hexachloroethane	<2.0			<1.0
1,2,4-trichlorobenzene	<2.0			<1.0
4-bromophenyl phenyl ether	<2.0			<1.0
2,4-dinitrotoluene	<2.0			<2.0
bis(2-ethylhexyl)phthalate	>3440			270.3
pentachlorobenzene	n/a			n/a
PAH, PCB (ug/L)				
acenaphthylene	<2.0			<1.0
acenaphthene	<2.0			<2.0
9H fluorene	<2.0			<1.0
phenanthene	<2.0			<1.0
anthracene	<2.0			<1.0
fluoranthene	<2.0			<1.0
pyrene	<2.0			<2.0
chrysene	<2.0			<2.0
benzo(A)anthracene	<2.0			<2.0
benzo(A)pyrene	<5.0			<2.0
benzo(K)fluoranthene	<5.0			<2.0
benzo(B) fluoranthene	<5.0			<2.0
dibenzo(AH)anthracene	<10.0			<2.0
benzo(GHI)perylene	<10.0			<2.0
indeno(123-CD)pyrene	<10.0			<2.0
polychlorinated biphenyls	<0.05			<0.1

TABLE L2
OWMC - WATER QUALITY
QA/QC DATA - 3 SEPTEMBER 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Pesticides and Herbicides (ug/L)				
beta-BHC	<0.002			<0.01
gamma-chlordane	<0.04			<0.02
alpha-chlordane	<0.04			<0.02
aldrin	0.003			<0.01
mirex	n/a			<0.015
endosulphan sulphate	n/a			<0.05
endrin	<0.002			<0.015
methoxychlor	n/a			<0.02
dieldrin	<0.001			<0.01
alpha-BHC	<0.001			<0.01
a-endosulphan-alpha	<0.001			<0.02
gamma-BHC (lindane)	<0.002			<0.01
endrin aldehyde	<0.002			n/a
toxaphene	<0.04			n/a
delta-BHC	<0.001			<0.01
p,p-DDD	<0.002			<0.02
p,p-DDE	<0.001			<0.02
oxychlordane	n/a			<0.025
heptachlor epoxide	<0.001			<0.015
heptachlor	<0.002			<0.01
p,p-DDT	<0.002			<0.02
b-endosiphan-beta	<0.001			<0.02
diazinon	n/a			<2.0
methylparathion	n/a			<1.0

TABLE L3
OWMC - WATER QUALITY
QA/QC DATA - 11 NOVEMBER 1986

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
GENERAL CHEMISTRY (mg/L)				
Collective Descriptors				
pH	7.99	7.5		
Conductivity (umho/cm)	431	355		
Total Dissolved Solids	298	293		
Turbidity (NTU)	41	86		
Alkalinity (as $CaCO_3$)	101	102		
Total Organic Carbon	20.0	16		
Major Cations				
Sodium	15.3	14		
Potassium	6.9	8.8		
Magnesium	17.4	16		
Calcium	47.6	45		
Major Anions				
Fluoride	0.22	0.16		
Chloride	25.8	25		
Bromide	<0.05	n/a		
Sulphate (as SO_4)	66.6	70		
Phosphate (as PO_4)	<0.1	0.086		
TRACE CONSTITUENTS				
Health (ug/L)				
Arsenic	1	1.3		
Cadmium	< 1	< 1		
Chromium	1	25		
Cyanide	< 4	2		
Lead	< 1	< 10		
Mercury	<0.05	< 0.1		
Sulphide	< 1	< 20		
Aesthetic (mg/L)				
Aluminum	2.03	7.5		
Copper (ug/L)	17	26		
Iron (ug/L)	3.08	4.5		
Manganese	0.084	0.10		
Phenols (ug/L)	< 1	11.2		
Zinc	0.238	0.028		
NUTRIENTS (mg/L)				
Ammonia-N	0.05	0.06		
Total Kjeldahl Nitrogen	0.97	0.178		
Total Phosphorus	0.200	.545		
Nitrate (as NO_3)	0.61	2.6		
Nitrite (as NO_2)	0.02	.036		
Biochemical Oxygen Demand (mg/L)		3.5	2	
BACTERIOLOGICAL (/100 mL)				
Total Coliform		22000	830	
Fecal Coliform		9	180	
Fecal Streptococci		18	80	
Background (/mL)		110000	1270	

TABLE L3
OWMC - WATER QUALITY
QA/QC DATA - 11 NOVEMBER 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Volatiles (ug/L)				
acrolein	<5.0			<10.0
1,1,1-trichlorethane	<1.0			<1.0
vinyl chloride	<2.0			<2.0
trichlorethylene	<1.0			<1.0
bromoform	<1.0			<1.0
1,4-dichlorobenzene	<2.0			TR
dichlorobromomethane	<1.0			<1.0
chloroform	<1.0			<1.0
benzene	<1.0			TR
acrylonitrile	<5.0			<10.0
1,2-dichlorobenzene	<2.0			<1.0
chlorobenzene	<1.0			<0.5
1,3-dichlorobenzene	<2.0			<1.0
1,1-dichloroethylene	<1.0			<1.0
1,3-dichloropropene	<1.0			<1.0
dibromochloromethane	<1.0			<1.0
o-xylene	n/a			<0.5
chloromethane	<2.0			<2.0
1,1,2-trichloroethane	<1.0			<1.0
carbon tetrachloride	<1.0			<1.0
1,1-dichloroethane	<1.0			<1.0
1,2-dichloropropane	<1.0			<1.0
toluene	0.4			<0.5
1,2-dichloroethane	<1.0			<1.0
tetrachloroethylene	<1.0			<1.0
p-xylene	n/a			<0.5
ethylbenzene	<1.0			<0.5
trichlorofluoromethane	<1.0			<2.0
chloroethane	<2.0			<2.0
1,1,2,2-tetrachloroethane	<1.0			<2.0
bromoethane	n/a			<5.0
1,2-t-dichloroethylene	<1.0			<1.0
m-xylene	n/a			<0.5
Acid Extractables (mainly phenols) (ug/L)				
pentachlorophenol	<5.0			<2.0
2-nitrophenol	<5.0			<5.0
4-nitrophenol	<5.0			<5.0
2,4-dichlorophenol	<5.0			<2.0
p-chloro-meta-cresol	n/a			<5.0
phenol	<5.0			<3.0
2,4,6-trichlorophenol	<5.0			<2.0
2,4-dinitrophenol	<10.0			<3.0
4,6-dinitro-o-cresol	n/a			<5.0
2,4-dimethylphenol	<10.0			<2.0
2,-chlorophenol	<5.0			<2.0
Base/Neutral Extractables (ug/L) (plastizers and misc. heavy organics)				
hexachlorocyclopentadiene	n/a			<1.0
isophorone	n/a			<1.0
nitrobenzene	<2.0			<1.0
bis(2-chloroisopropyl)ether	<2.0			<1.0
dimethyl phthalate	<2.0			<2.0

TABLE L3
OWMC - WATER QUALITY
QA/QC DATA - 11 NOVEMBER 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Base Neutral Extractables (ug/L)				
napthalene	<2.0			<1.0
bis(2-chloroethoxy)methane	<2.0			<2.0
hexachlorobutadience	<2.0			<1.0
4-chlorophenyl phenyl ether	<2.0			<1.0
di-n-butylphthalate	1.2			1.7
2,6-dinitrotoluene	<2.0			<2.0
benzidine	n/a			<5.0
2-chloronaphthalene	0.3			<1.0
butyl benzyl phthalate	22.7			<2.0
N-nitroso-n-propylamine	<20.0			<3.0
di-n-octylphthalate	19.3			<2.0
bis(2-chloroethyl)ether	<2.0			<1.0
diethylphthalate	4.7			<2.0
1,2-diphenylhydrazine	n/a			<5.0
3,3'-dichlorobenzidine	<20.0			<5.0
N-nitrosodiphenylamine	n/a			<4.0
2-chloroethyl vinyl ether	<1.0			n/a
hexachlorobenzene	<2.0			TR
hexachloroethane	<2.0			<1.0
1,2,4-trichlorobenzene	<2.0			<1.0
4-bromophenyl phenyl ether	<2.0			<1.0
2,4-dinitrotoluene	<2.0			<2.0
bis(2-ethylhexyl)phthalate	<17.0			30.1
PAH, PCB (ug/L)				
acenaphthylene	<2.0			<1.0
acenaphthene	<2.0			<1.0
9H fluorene	<2.0			<1.0
phenanthene	0.2			<1.0
anthracene	0.2			<1.0
fluoranthene	<2.0			<1.0
pyrene	<2.0			<2.0
chrysene	<2.0			<2.0
benzo(A)anthracene	<2.0			<2.0
benzo(A)pyrene	<5.0			<2.0
benzo(K)fluoranthene	<5.0			<2.0
benzo(B) fluoranthene	<5.0			<2.0
dibenzo(AH)anthracene	<10.0			<2.0
benzo(GHI)perylene	<10.0			<2.0
indeno(123-CD)pyrene	<10.0			<2.0
polychlorinated biphenyls	<0.05			<0.1

TABLE L3
OWMC - WATER QUALITY
QA/QC DATA - 11 NOVEMBER 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Pesticides and Herbicides (ug/L)				
beta-BHC	<0.002			<0.01
gamma-chlordane	<0.04			<0.02
alpha-chlordane	<0.04			<0.02
aldrin	<0.001			<0.01
mirex	n/a			<0.015
endosulphan sulphate	n/a			<0.05
endrin	<0.002			<0.015
methoxychlor	n/a			<0.02
dieldrin	<0.001			<0.01
alpha-BHC	0.003			<0.01
a-endosulphan-alpha	<0.001			<0.02
gamma-BHC (lindane)	<0.002			<0.01
endrin aldehyde	<0.002			n/a
toxaphene	<0.4			n/a
delta-BHC	<0.001			<0.01
p,p-DDD	<0.002			<0.02
p,p-DDE	<0.001			<0.02
oxychlordane	n/a			<0.025
heptachlor epoxide	<0.001			<0.015
heptachlor	0.019			<0.01
p,p-DDT	<0.002			<0.02
b-endoslphan-beta	<0.001			<0.02
2,4-5-T	n/a			<0.2
2,4-D	n/a			<0.2
Silvex	n/a			<0.2
diazinon	n/a			<0.5
methylparathion	n/a			<1.0

TABLE L4
OWMC SEDIMENT QUALITY
QA/QC DATA - 3 SEPTEMBER 1986

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
GENERAL CHEMISTRY (mg/kg)				
Collective Descriptors				
Total Solids, %	n/a	28.1		
Volatile Solids, % dry wt.	n/a	16.3		
Major Cations				
Sodium	330	196		
Potassium	10,100	6,410		
Magnesium	11,300	17,400		
Calcium	9,480	18,900		
Major Anions				
Fluoride	3.92	n/a		
Chloride	123	128		
Bromide	< 0.5	n/a		
Sulphate (as SO_4)	238	750		
Phosphate (as PO_4)	< 1	<0.3		
TRACE CONSTITUENTS (mg/kg)				
Health				
Arsenic	7.75	5.7		
Cadmium	< 0.5	0.4		
Chromium	12.6	12		
Cyanide	0.2	n/a		
Lead	20	25		
Mercury	n/a	0.11		
Sulfide	5,490	n/a		
Aesthetic				
Aluminum	40,800	60,500		
Copper	28.7	33		
Iron	35,800	60,500		
Manganese	530	604		
Zinc	106	130		
NUTRIENTS (mg/kg)				
Ammonia-N	616	85		
Total Kjeldahl Nitrogen	4,060	5,590		
Total Phosphorus	974	1,030		
Nitrate (as NO_3)	< 0.5	< 0.3		
Nitrite (as NO_2)	< 2.0	< 0.1		

TABLE L4
OWMC SEDIMENT QUALITY
QA/QC DATA - 3 SEPTEMBER 1986
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
Acid Extractables (mainly phenols) (mg/kg)				
pentachlorphenol	< 5	<0.2		
2-nitrophenol	< 5	<0.5		
4-nitrophenol	< 5	<0.5		
2,4-dichlorophenol	< 5	<0.2		
2,4-5-trichlorophenol	n/a	n/a		
p-chloro-meta-cresol	n/a	<0.5		
phenol	< 5	<0.3		
2,3,4,5-tetrachlorophenol	n/a	n/a		
2,4,6-trichlorophenol	< 5	<0.2		
2,3,5,6-tetrachlorophenol	n/a	n/a		
2,4-dinitrophenol	<10	<0.3		
4,6-dinitro-o-cresol	n/a	<0.5		
2,4-dimethylphenol	<10	<0.2		
2-chlorophenol	< 5	<0.2		
Base/Neutral Extractables (mg/kg) (plastizers and misc. heavy organics)				
hexachlorocyclopentadiene	n/a			<0.1
isophorone	n/a			<0.1
nitrobenzene	< 2			<0.1
bis(2-chloroisopropyl)ether	< 2			<0.1
dimethyl phthalate	< 2			<0.2
napthalene	< 2			<0.1
bis(2-chloroethoxy)methane	< 2			<0.2
hexachlorobutadiene	< 2			<0.1
4-chlorophenyl phenyl ether	< 2			<0.1
di-n-butylphthalate	n/a			<0.1
2,6-dinitrotoluene	< 2			n/a
benzidine	n/a			<0.5
2-chloronaphthalene	< 2			<0.1
butyl benzyl phthalate	n/a			<0.2
N-nitroso-n-propylamine	n/a			<0.3
di-n-octylphthalate	n/a			<0.2
bis(2-chloroethyl)ether	< 2			<0.1
diethylphthalate	< 2			<0.2
1,2-diphenylhydrazine	n/a			<0.5
3,3'-dichlorobenzidine	n/a			<0.5
N-nitrosodiphenylamine	n/a			<0.4
hexachlorobenzene	< 2			<0.1
hexachloroethane	< 2			<0.1
1,2,4-trichlorobenzene	< 2			<0.1
4-bromophenyl phenyl ether	n/a			<0.1
2,4-dinitrotoluene	n/a			<0.2
bis(2-ethylhexyl)phthalate	n/a			1.298

TABLE L4
OWMC SEDIMENT QUALITY
QA/QC DATA - 3 SEPTEMBER 1987
(continued)

PARAMETER	LABORATORY			
	BML	ORF	SBL	MAN
PRIORITY ORGANICS				
PAH, PCB (mg/kg)				
acenaphthylene	< 2			<0.1
acenaphthene	< 2			<0.1
9H fluorene	n/a			<0.1
phenanthrene	< 2			<0.1
anthracene	< 2			<0.1
fluoranthene	n/a			<0.1
pyrene	n/a			<0.2
chrysene	n/a			<0.2
benzo(A)anthracene	n/a			<0.2
benzo(A)pyrene	n/a			<0.2
benzo(K)fluoranthene	n/a			<0.2
benzo(B)fluoranthene	n/a			<0.2
dibenzo(AH)anthracene	n/a			<0.2
benzo(GHI)perylene	n/a			<0.2
indeno(123-CD)pyrene	n/a			<0.2
polychlorinated biphenyls	< 1			<0.030
Pesticides and Herbicides (ug/kg)				
beta-BHC	< 1			<1.0
gamma-chlordane	n/a			<3.0
alpha-chlordane	< 1			<3.0
aldrin	< 1			<1.0
mirex	n/a			<2.0
endosulphan sulphate	n/a			<3.0
endrin	< 1			<1.0
methoxychlor	n/a			<3.0
dieldrin	< 1			<1.0
alpha-BHC	< 1			<1.0
a-endosulphan-alpha	< 1			<2.0
gamma-BHC (lindane)	< 1			<1.0
endrin aldehyde	< 1			n/a
toxaphene	< 1			n/a
delta-BHC	< 1			<1.0
p,p-DDD	< 1			<2.0
o,p-DDT	< 1			<2.0
p,p-DDE	< 1			<2.0
oxychlordane	n/a			<3.0
heptachlor epoxide	< 1			<1.5
heptachlor	< 2			<1.0
b-endosulphan-beta	< 1			<2.0
2,4,5-T	n/a			<5.0
2,4-D	n/a			<5.0
silvex	n/a			<5.0
diazinon	n/a			<2.0
methylparathion	n/a			<1.0

TABLE L5

FIELD BLANK DATA

PARAMETER GROUPING: GENERAL CHEMISTRY

ALL DATA IN MG/L EXCEPT AS NOTED IN TABLE K1

	FIELD DATA				COLLECTIVE DESCRIPTORS				MAJOR CATIONS				MAJOR ANIONS					
DATE	T	pH	DO	COND	TDS	TURB	ALK	TOC	Na	K	Mg	Ca	F	Cl	Br	NO3	SO4	PO4
19860214	n/a	n/a	n/a	n/a	6	<1	2.0	<.5	<.1	<.1	.005	.02	<.005	<.01	<.05	<.05	<.05	<.1
19860311	n/a	n/a	n/a	n/a	9	<1	1.0	.5	<.2	<.2	<.01	.108	<.005	<.01	<.05	.20	<.05	<.1
19860402	n/a	n/a	n/a	n/a	<1	<1	4.1	.5	<.2	<.2	.024	.114	<.005	<.01	<.05	<.05	<.05	<.1
19860903	n/a	n/a	n/a	n/a	<1	<1	20.0	.5	<.2	<.2	.020	.067	<.005	<.01	<.05	<.05	<.05	<.1
19861111	n/a	n/a	n/a	n/a	<2	<1	4.0	<.5	<.2	<.2	.059	.255	<.005	.52	<.05	<.05	<.05	<.1

TABLE L6

FIELD BLANK DATA

PARAMETER GROUPING: NUTRIENTS & BACTERIOLOGICAL

NUTRIENT DATA IN MG/L, BACTERIOLOGICAL IN COUNTS/100 mL
EXCEPT AS NOTED IN TABLE K1

	NUTRIENTS						BACTERIOLOGICAL			
DATE	NH3	TKN	TOTP	NO3	NO2	BOD	TC	FC	FS	BGND
19860214	<.02	<.05	<.01	<.05	<.02	<0.1	<1	<1	5	67
19860311	<.02	<.05	<.01	.20	<.02	5	<1	<1	<1	6400
19860402	<.02	.16	<.01	<.05	<.02	4	<1	<1	<1	24
19860903	.11	.12	<.01	<.05	<.02	<1	880	170	13	190
19861111	<.05	<.05	<.01	<.05	<.02	29	0	0	0	20

TABLE L7

FIELD BLANK DATA

PARAMETER GROUPING: TRACE CONSTITUENTS

ALL DATA IN UG/L

	HEALTH							AESTHETIC					
DATE	As	Cd	Cr	CN	Pb	Hg	S	Al	Cu	Fe	Mn	PHEN	Zn
19860214	<1	<1	<1	<4	<5	<.05	2	2	<.8	5	<1	<1	8
19860311	<1	<2	<1	<4	<1	<.05	<1	16	2	28	<2	<1	<10
19860402	<1	<1	18	7	2	<.05	<1	20	3	24	<2	<1	<10
19860903	<1	<1	<1	<4	<1	<.05	<1	22	19	7	<2	<1	13
19861111	<1	<1	1	<4	<1	<.05	<1	41	16	51	<2	<1	124

TABLE L8

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACR	TRIC	VCM	TCE	MEBR	14DB	MEBRCL2	MECL3	PHI	ACN	12DB	CB	MEF2CL2	11DCE	13DCP
19860214	<5	<2	<5	<2	<2	n/a	<2	<2	<2	<5	n/a	<2	<5	<2	<2
19860402	<5	<2	<5	<2	<2	n/a	<2	9.3	<2	<5	n/a	<2	<5	<2	<2
19860903	n/a	1.1	<2	<1	<1	<1	<1	TR	<0.5	n/a	<1	<0.5	<2	<1	n/a
19861111	<10	<1	<2	<1	<1	<1	TR	58.5	TR	<10	<1	<0.5	<2	<1	<1

TABLE L9

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - VOLATILES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	OPHIX	MECL	112TCE	CCL4	12DCP	PHIME	12DCE	PCE	PPHIX	ETPHI	MEFCL3	1122TCE	BRET	12DCET	MPHIX
19860214	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19860402	n/a	<5	<2	<2	<2	<2	<2	<2	n/a	<2	<2	<2	n/a	<2	n/a
19860903	<0.5	<2	<1	<1	<1	TR	<1	TR	TR	<0.5	<2	<1	n/a	<1	TR
19861111	<0.5	<2	<1	<1	<1	TR	<1	<1	<0.5	<0.5	<2	<2	<5	<1	<0.5

TABLE L10

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - ACID EXTRACTABLES (MAINLY PHENOLS)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	PCP	2NP	4NP	24CP	245TCP	234TCP	PCMC	P	2345TCP	246TCP	2356TCP	24NP	46NC	24MEP	2CP
19860214	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2
19860903	<2	<5	<5	<2	n/a	n/a	<5	<3	n/a	<2	n/a	<3	<5	<2	<2

TABLE L11

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCCP	ISOP	NP	BCIPE	DMPH	NPHTH	BCEME	HCBD	4CPPE	DBPH	26NT	BZID	2CNP
19860214	<1	<1	<1	<1	<2	<1	<2	<1	<1	<1	<2	<5	<1
19860903	<1	<1	<1	<1	<2	<1	<2	<1	<1	3.0	<2	<5	<1

TABLE L12

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBP	NPA	DOP	BCE	236TCT	DEP	12PH	33CBZID	NMA	NPA	CVE	BPHI	HCB	1245TCB
19860214	<2	<3	<2	<1	n/a	<2	<5	<5	n/a	<4	n/a	n/a	<1	n/a
19860903	<2	<3	<2	<1	n/a	5.2	<5	<5	n/a	<4	n/a	n/a	<1	n/a

TABLE L13

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - BASE/NEUTRAL EXTRACTABLES (CONTINUED)

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	HCE	DPE	1234TCB	1235TCB	123TCB	124TCB	BPE	24NT	245TCT	BCMEE	135TCB	D2EP	PCPHI
19860214	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	9.0	n/a
19860903	<1	n/a	n/a	n/a	n/a	<1	<1	<2	n/a	n/a	n/a	41.1	n/a

TABLE L14

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - PAH,PCB

ALL DATA IN UG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	ACNY	ACN	9HF	PHEN	ANTH	FLUOR	PYR	CHR	BAA	BAP	BKFA	BBFA	BAHA	BPERY	INDOP	MEPHEN	PCB
19860214	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100
19860903	<1	<1	<1	<1	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	n/a	<100

TABLE L15

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	BBHC	CCD	ACD	ALD	MIR	ENDOS	END	MECH	DIEL	ABHC	AENDOS	LIND	ENDA	TOX	DBHC
19860214	<10	<25	<25	TR	<50	n/a	<20	<20	<45	<10	<25	<10	n/a	n/a	n/a
19860903	<10	<20	<20	<10	<15	n/a	<15	<20	<10	<10	<20	<10	n/a	n/a	n/a

TABLE L16

FIELD BLANK DATA

PARAMETER GROUPING: PRIORITY ORGANICS - PESTICIDES & HERBICIDES (CONTINUED)

ALL DATA IN NG/L,LESS THAN ENTRIES LIST METHOD DETECTION LIMIT

DATE	DDD	OPDDT	DDE	OXYC	HEPTE	HEPT	PPDDT	BENDOS	T245	D24	SILV	DIAZ	MEPARA	PARA	ALA	ATR
19860214	<20	n/a	<20	<25	<20	<15	<20	<25	n/a	n/a	n/a	<400	<200	n/a	n/a	<200
19860903	<20	n/a	<20	<25	<15	<10	<20	<20	<200	<200	<200	<500	<1000	n/a	n/a	<1000

Final report

OWMC
Ontario
Waste Management
Corporation

A provincial crown corporation

DILLON

SITE ASSESSMENT
PHASE 4B:
SURFACE WATER
VOLUME 3 -
FIELD AND LABORATORY PROTOCOLS

Prepared for
The Ontario Waste Management Corporation

Submitted By

M.M. Dillon Limited
Consulting Engineers and Planners

October, 1987

DILLON
Consulting Engineers • Planners
Environmental Scientists

9925-31-1

OUR FILE:
YOUR FILE:

30 October 1987

Mr. J.G. Micak
Ontario Waste Management Corporation
2 Bloor Street West
11th Floor
Toronto, Ontario
M4W 3E2

Attention: Mr. D.F. Chollak
Environmental Planner

Site Assessment - Phase 4B
Surface Water, Volume 3 -
Field and Laboratory Protocols

Dear Sirs:

We are pleased to submit the Final Report for the Phase 4B, Site Assessment on Surface Water. The report has been divided into three volumes and presents the results of our study of baseline conditions and impact assessment.

Volume 3 (this volume) details the procedures used for conducting water quality sampling and streamflow measurements, quality assurance requirements and detailed analytical and laboratory quality control procedures.

We look forward to assisting you with the approvals for and implementation of this very important project.

Yours truly,

M. M. DILLON LIMITED

A.K. Mitchell

A.K. Mitchell, P.Eng.
Project Manager

AKM:mrb
Attach.

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APPENDIX B - DETAILED ANALYTICAL AND LABORATORY QUALITY CONTROL PROCEDURES

CHAPTER 1
INTRODUCTION

M.M. Dillon Limited (MMD) and Gartner Lee Limited (GLL) were selected by the Ontario Waste Management Corporation (OWMC) to evaluate the existing water quality and water quantity in the vicinity of the preferred site. This evaluation is required to establish a baseline for the quality of the surface water bodies (Sucker Creek and the Welland River) that may be affected by operations at the site. The quantity of water flowing in these bodies is similarly being evaluated.

It is imperative, for the purposes of this evaluation, to obtain a reliable estimate of water quality and quantity in Sucker Creek and the Welland River. As a result, procedures for collecting verifiably reliable water quality and water quantity data have been prepared and are detailed in this protocol document. Data quality has been defined as follows by T.W. Stanley, Coordinator of Quality Assurance, National Bureau of Standards (Taylor, 1985).

"The quality of data is ordinarily evaluated on the basis of its uncertainty when compared with end-use requirements. If the data have consistency and a small uncertainty when compared with the requirements, they are considered to be of adequate quality. When they are excessively variable or when the level of uncertainty exceeds the needs, the quality may be said to be low or inadequate. The evaluation of data quality is thus a relative determination. What is high quality for one situation could be unacceptable in another."

The water quality and quantity data obtained in this assessment must provide a reliable estimate of the actual quality and quantity of the water. As well, the data collected and the procedures used must be documented and defensible in an Environmental Assessment hearing. The procedures, quality assurance methods and documentation presented in this protocol document will insure that data with "consistency and a small uncertainty" will be collected.

This protocol document is effectively a "how-to" manual with detailed procedures for collecting water samples from creeks and rivers. Procedures for the laboratory analysis of water quality parameters are detailed in Appendix 'B' to this document. These procedures, including quality assurance methodologies, have been provided directly by the four laboratories involved in the 1986 monitoring program. For simplicity and ease of use of this manual, the rationales for implementing the chosen procedures are omitted. These have been noted, and will be reported separately from the protocol document itself.

1.1 ASSUMPTIONS

In order to develop procedures for the collection of water quality and quantity data, certain factors have to be presumed. These are:

- analytical parameters for the determination of water quality;
- sampling locations (on Sucker Creek, 9C Creek and the Welland River);
- sampling frequency.

The analytical parameters required for water quality assessment and the sampling locations and frequencies have been determined by the study team in conjunction with OWMC, and are described elsewhere. They have, however been taken into consideration in the development of the sampling/testing procedures shown in this document.

1.2 QUALITY ASSURANCE AND QUALITY CONTROL

The overriding premise for this water quality and quantity assessment is that high quality data must be collected. These data must be as accurate as possible, i.e. must come as close as possible to representing the actual water quality and quantity in the watercourses under existing conditions. The data must also be precise, consistent and well documented in order to meet the requirements of this assessment. A rigorous quality assurance system has been implemented, with associated quality control procedures, to ensure this.

Quality assurance can be defined as: "those operations and procedures which are undertaken to provide measurement data of stated quality with a stated probability of being right" (Taylor, 1985). More specifically, quality assurance can be divided into two separate components. Quality assurance itself is a management function in which quality control procedures are developed, operational procedures are described in detail in a formal

protocol, employees are trained in both quality control and operations, and quality control data are checked. The protocol document is a very important part of the quality assurance implemented in this assessment. Sampling procedures for both water quality and quantity as well as analytical procedures are detailed in this protocol document. Therefore this document is a permanent record of procedures used in the assessment. As well, it forms a procedures manual for the training of field and laboratory technicians.

Quality control procedures are procedures implemented by the field or laboratory technician which help ensure that the methods being used for field sampling and analysis are operating according to specification. For water quality assessment these quality control procedures include:

- collection of duplicate field samples and field blank samples for analysis;
- labelling and documenting of field samples;
- regular analysis of duplicate samples, samples of known concentration, and distilled water blank samples, to ensure that the analytical systems are operating correctly;
- analysis of duplicate samples by different laboratories to ensure that comparable results are obtained.

These specific quality control procedures are detailed in the appropriate chapters of this document. Detailed laboratory quality control and analytical procedures are appended.

One aspect of quality assurance will be consistently followed throughout this water quality and quantity assessment. Field sampling, analysis, etc. will be undertaken <u>only</u> by personnel trained in these activities using procedures documented in this manual.

CHAPTER 2
STREAMFLOW DATA ACQUISITION

This section describes the protocols covering all aspects of the collection, reduction, and storage of stream discharge data. It includes a description of the equipment to be used, its installation and operation, and procedures for the collection of data from the field. Finally, the reduction of the data to a usable form and the storage of data in a retrievable form is detailed.

In addition to data that are collected from the site vicinity by GLL/MMD staff some data will be collected from other agencies for stations in the vicinity of the site. Data from the Ministry of the Environment (MOE) Water Resources Branch and the Water Survey of Canada include the following items for the current year and historical periods:

- Streamflow data for monitoring stations on the Welland River
  - 2HA007, Welland River below Caistor Corners
  - 2HA015, Welland River near Mount Hope
- Streamflow data from PLUARG/IHD Basins in the vicinity of the of the site.

2.1 INSTRUMENTATION AND EQUIPMENT

The streamflow quantity measuring instrumentation proposed for this site may consist of any of the following items:

- Staff gauges to measure water levels.
- Water level recorders to measure and record water levels automatically and continuously.
- Calibrated stream cross section or weir.
- Water velocity meters.

2.1.1 STAFF GAUGES

Standard metric staff gauges will be installed at several locations in the vicinity of the site. Locations are selected to meet the needs of the OWMC Surface Water Resources Study.

Within each stream or watercourse, the location is chosen to provide water levels of a pool through which the flow is (naturally) regulated by a good hydraulic stream cross section.

Each installation consists of a metric gauge face plate mounted vertically on a piece of treated timber. The timber is securely bolted to a steel fence post driven at least 1.5 m into the base of the stream. The fence post is positioned where the stream will continue to pond during periods of low flow, but out of the main stream, to avoid damage to the gauge from flood flows and from ice during the spring breakup. The gauge plate is mounted low enough to show the water level during the low flow season, including times when the flow ceases.

Wherever possible, the gauges are placed facing the access to make readings easier.

After installation, the elevation of the gauge is referenced to some immovable object to permit checking it for vertical movement (e.g. due to flood damage, frost heave, or malicious tampering). A surveyed bench mark or culvert/bridge has been used. Consideration was given to installing a more permanent installation. However, staff gauges were installed after spring break-up and are required for only a year period in this study. Some repair of staff gauges may be required annually due to damage from large ice flows during spring break up.

2.1.2 WATER LEVEL RECORDER

At one location an automatic water level recorder may be installed in conjunction with a calibrated stream cross section.

A Stevens Type A-71 or equivalent is to be installed according to the manufacturer's instruction on top of a robustly constructed stilling well. Detailed procedures for installation and maintenance are also outlined in Trinidad Water Resources Survey - Procedures (Dillon, 1969), and are applicable to this installation.

The recorder must be housed in a weather proof and secure cabinet.

The components of the recorder are selected to provide an instrument capable of operating year round. The recorder is protected from the effects of low temperatures. Scales, charts, and gearing are all in the International System of Units (SI). Other features of the specification are matched to the range of water levels anticipated in the stream, and the stilling well dimensions.

The stilling well is constructed of permanent materials (corrugated steel pipe), and secured against toppling, flooding and malicious damage. A staff gauge is erected close to the recorder to allow the "setting-up" of the recorder. This staff gauge is also levelled to a local bench mark.

2.1.3 CALIBRATED CROSS SECTION

Depending on the quality of the data collected during the early stages of the study a calibrated cross section may be installed, downstream from the water level recorder. This installation may be a reshaping of the streambed and banks to improve the "rating" of the section, or could include the construction of a calibrated (V-notch) weir in the streambed. Either must withstand continuous use during the life of the monitoring station.

2.1.4 WATER VELOCITY METERS

The discharge of a stream is measured manually by streamflow gauging. It is based on the measurement of water velocities in a regular pattern across a stream of a measured geometrical shape, and the calculation of a discharge (refer to Section 2.2.2).

Types of water velocity meters are:

- Rotating bucket or anemometer e.g. Gurley or Pygmy
- Propellor e.g. Ott C-41 or similar
- Electronic or electomagnetic e.g. Marsh-McBurnie

For this project, the meters must be recalibrated at CCIW within 12 months prior to start of the project and again annually. A field "spin test" is conducted prior to and after use on each day (refer to Section 2.2.2 vii).

2.2 FIELD MEASUREMENTS

2.2.1 WATER LEVEL OBSERVATIONS

The water levels at staff gauges are recorded (sample form in Appendix 'A') noting the condition of the gauge, damage, etc. The face plate is kept clean of algae and other aquatic growth. The level of the gauge with respect to the reference point is checked each spring, after the frost is out of the ground.

The water level recorder is checked to see that the correct water level is being marked on the chart. On each inspection the water level reading from the staff gauge, date, and time are recorded on the chart for future reference.

2.2.2 STREAM DISCHARGE MEASUREMENT BY CURRENT METER

This procedure covers the methods of computing discharge from measurements of the cross sectional area of the stream and the mean velocity, and the methods to be employed in the field.

i) Theory

This discharge (Q) in cubic metres per second (m^3/s) through a stream cross section at any particular time is given by:

$$Q = A.\overline{V}\ m^3/s$$

where A = cross sectional area of the flow in m^2

$\overline{V}$ = the mean velocity in the cross section in m/s

This mean velocity ($\overline{V}$) cannot be measured directly as [illegible] nature the velocity varies from point to point in a channel

cross section due to the different resistance offered by the bed, banks and free water surface.

A typical velocity distribution in a channel is shown in Figure 1.

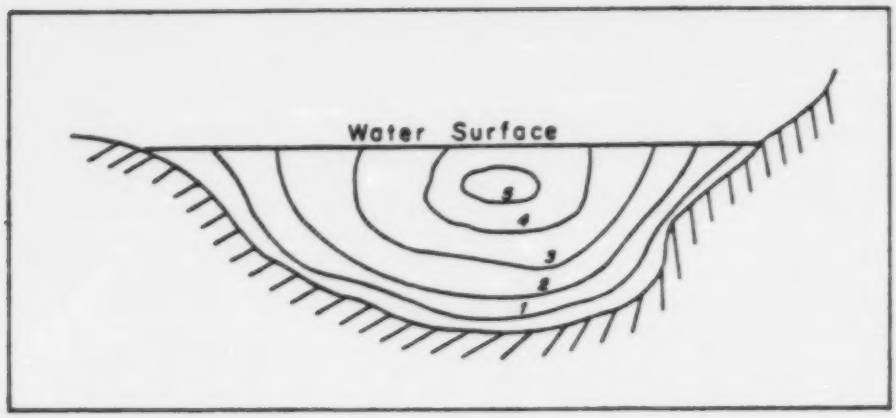

FIGURE 1

Various methods are available for determining the discharge from measurements of cross sectional area and point velocities in the section. The methods to be used by the Phase 4B - Surface Water Resources Study are described under ii) Methods of Computing Discharge.

The fastest and simplest methods involve dividing the stream cross section into smaller sections which are bounded by the free water surface, the stream bed and two imaginary verticals extending from surface to bed. The <u>mean velocity in each vertical</u> is then obtained by current metering and this is used to determine the <u>mean velocity in the small section</u>.

In order to determine the mean velocity in each vertical a knowledge of the velocity distribution in the vertical is required.

If a sufficient number of point velocity measurements are made in the vertical, it is possible to plot the vertical velocity curve (refer to Figure 2).

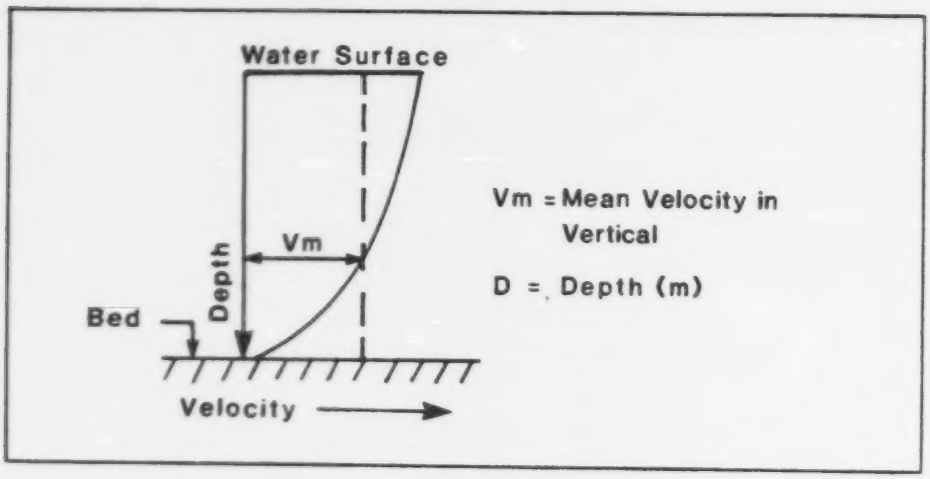

FIGURE 2

Fortunately, it has been found from studies of many actual observations that the arithmetic average of velocities at certain depths give a value of the mean velocity in the vertical, which is very close to the true value.

The combinations to be used for arithmetic averaging are given in Table 1.

TABLE 1

Number of Points in Vertical	Location of Points in Vertical in Fraction of Total Depth of Vertical Measured from the Water Surface
1	0.6 D
1	0.5 D
2	0.2 D, 0.8 D
3	0.2 D, 0.6 D, 0.8 D

NOTE:

The mean velocity in the vertical may be obtained arithmetically as follows:

$$1 \text{ point } Vm = V \text{ at } 0.6D$$

$$1 \text{ point } Vm = 0.96 \times V \text{ at } 0.5D$$

$$2 \text{ point } Vm = \frac{V \text{ at } 0.2D + V \text{ at } 0.8D}{2}$$

$$3 \text{ point } Vm = \frac{V \text{ at } 0.2D + V \text{ at } 0.6D + V \text{ at } 0.8D}{3}$$

OR

$$Vm = \frac{(V \text{ at } 0.2D + V \text{ at } 0.8D)}{2} + V \text{ at } 0.6D \quad /2$$

With an understanding of the velocity distribution over the section it is possible to consider the methods available for obtaining discharge using a current meter.

ii) Methods of Computing Discharge

The commonly used methods of computing discharge are classified as: arithmetic methods and graphical methods. For the OWMC Surface Water Resources Study, a suitable arithmetic method is adopted as follows:

Mean Section Method

When velocities are measured at one, two or three points in the vertical and the mean velocity in the vertical is obtained by arithmetic averaging, the following mean section method is used to compute discharge.

The cross section is regarded as being made up of a number of panels, each bounded by two adjacent verticals as shown in Figure 3.

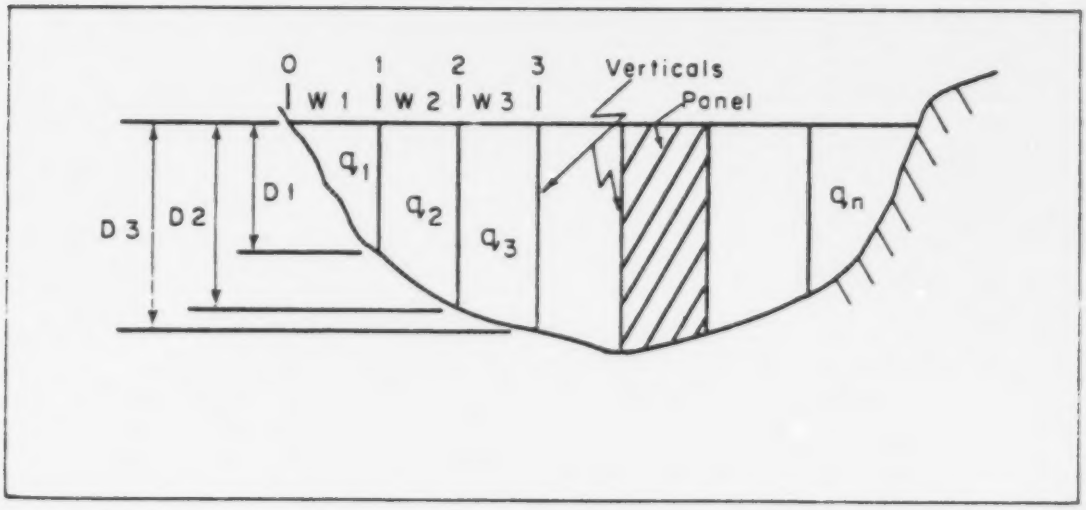

FIGURE 3

The discharge (q) through each panel may be calculated as shown below, where Vm 1, Vm 2, Vm 3 are the mean velocities in verticals (1), (2), and (3).

$$q_1 = \frac{W1, D1}{2} \cdot \frac{Vm\ 1}{2} \quad \text{(end panel, mean velocity)}$$

(assumed to be $\frac{Vm\ 1}{2}$)

$$q_2 = W2\ \frac{(D1 + D2)}{2} \cdot \frac{(Vm\ 1 + Vm\ 2)}{2}$$

$$q_3 = W3\ \frac{(D2 + D3)}{2} \cdot \frac{(Vm\ 2 + Vm\ 3)}{2}$$

etc.

The total discharge (Q) through the cross section is obtained by summing the panel discharge, i.e.:

$$Q = q_1 + q_2 + q_3 + \dots q_n$$

therefore $Q = \sum_{o}^{n} q$ m^3/s if velocities are in m^3/s and dimensions in meters

iii) Selection of Location of Verticals in a Cross Section

The number of verticals in a cross section depends on the regularity of the velocity distribution, the geometry of the section and the time available for the discharge measurement.

The verticals should be located keeping in mind:

1. The profile of the bed and banks below the water surface at the time of the discharge measurement must be accurately determined.

2. The verticals must be spaced sufficiently close together to prevent any serious error being introduced by the assumption that velocity varies linearly between verticals.

The following general rules for spacing of verticals are to be followed:

- the discharge in each panel (between verticals) shall be approximately equal;
- the largest flow through any one panel shall not be greater than about ten (10) percent of the total discharge;
- the error in determining the panel area by assuming that the bed profile between verticals is a straight line shall not exceed three (3) percent;
- the difference between mean velocities in adjacent verticals does not exceed twenty (20) percent of the lesser of the two.

The foregoing can generally be complied with, by using 15 to 20 verticals well distributed across the section. In any case, the number should not be less than 10, except for measurement of very small streams with a water surface width of 1 to 1.5 m or less when 6 verticals may be used.

The verticals will not generally be evenly spaced and will usually be closer spaced over that part of the stream section which carries the biggest portion of the flow, i.e. for a fairly uniform section the spacing will be closer at the centre than at the edges. Observation of surface velocities prior to "current metering" is a good guide as to where the verticals should be located.

iv) Number of Point Velocity Measurements in a Vertical

Two point velocities (i.e. at .2D and .8D) will generally be used. When the depth is insufficient for two point observations, one point (.6D or .5D) velocity will be measured.

For any observation point the horizontal axis of the meter rotor shall not be closer to the surface or bed of the stream than 1/1-2 times the vertical dimension of the rotor (cups or propeller). For irregular stream bottoms, the meter should be kept sufficiently far above the bed to avoid turbulence caused by stones, debris, etc.

v) Time Needed to Obtain Point Velocity

After the current meter has been placed at the correct location in the vertical, the velocity at that point may be obtained by counting the number of revolutions made by the rotor in a certain time or vice versa, and using the rating table for the particular meter.

The period for the velocity measurement should not be less than 40 seconds and, except for very low velocities should not exceed 70 seconds.

A single measured period of 60 seconds yields good results in most cases and simplifies the calculation of velocity from the meter rating table. This will be used generally for the OWMC program.

Care should be taken when using automatic counters as they over register by one revolution when the counter is switched on and off.

An average of two or three "40 or 60 second velocities" will yield a more accurate value than the single value but only one observation will normally be made at each point due to the amount of time required to obtain the extra values.

After the meter has been placed at the correct location in the vertical, it is good practice to wait 10 seconds or longer before observing and timing the number of revolutions. This minimizes the errors caused by the disturbance in placing the meter.

vi) Observation of Stage During Discharge Measurement

Discharge measurement using a current meter should preferably be made only during relatively steady flow conditions.

As the discharge measurement is to be used in establishing the stage-discharge relationship at the gauging station, it is essential that the stage be observed during the measurement.

It is good practice to measure stage directly during discharge measurement (i.e. by tape from an index or reference mark or an external staff gauge reading).

vii) Spin Test

The spin test is a common method for determining the condition of the meter. In making a spin test, the meter should be so placed that the shaft is in a true vertical position and the bucket wheel protected from air currents. The bucket wheel is then given a quick turn to start it spinning. As the rotating bucket wheel nears the stopping point, it should be carefully observed to see whether the stop is abrupt or gradual. The bearings of any meter having a bucket wheel

that will spin 1/1-2 minutes and come to a gradual stop are in satisfactory condition for measuring all except very low velocities. If the spin is 1 minute and the meter is in satisfactory condition in all other respects, the meter may be used to measure velocities above 0.3 m/s without appreciable error.

2.2.3 DATA REDUCTION

The streamflow data is intended to provide values for the discharge of the streams, either continuously or at specific times. The discharge is either measured manually by streamflow gauging, or calculated from equations using the geometry of a calibrated cross-section and the level of the water. From these measurements and calculations, Rating Curves are developed for each streamflow station, relating the elevation of the water surface at a staff gauge to the discharge. After Rating Curves have been developed, streamflow gauging need only be done infrequently to measure extreme events or to check the Curve.

When stream discharge data has been measured or calculated then it is stored for later use.

CHAPTER 3
SURFACE WATER QUALITY DATA ACQUISITION

3.1 GENERAL CONSIDERATIONS

The collection of water samples that are representative of the temporal and spatial variability of the water bodies under study requires a careful consideration of many factors, including:

- study objectives and precision requirements of the data,
- the natural variability of the system,
- station location, and
- sample collection techniques.

One of the objectives of the Phase 4B-Surface Water Resources Study is to provide information on the existing water quality conditions in the vicinity of OWMC's preferred site as part of an analysis of impact and risk from the development of a hazardous waste treatment facility at this Site. Secondly, data is to be collected as part of an environmental baseline against which

future monitoring can be compared. The collection of water quality data for monitoring purposes is not an objective of the present study.

Basic information requirements for the impact/risk analysis are summarized below:

- streamflow information, especially during periods of low flow,
- concentrations of water quality parameters in the watercourses in the vicinity of the site, and
- estimates of the loading of these substances to the stream system.

Four water quality monitoring stations have been identified as being suitable for the collection of water quality data for input to the impact/risk assessment analysis and environmental baseline. The stations were selected to provide the following information:

- the water quality of the stream which currently drains the preferred site (9C Creek),
- the water quality of the stream which currently drains the area to the north and east of the site (Sucker Creek),
- water quality in the Welland River, both upstream (at Wellandport) and downstream (at Pearson Bridge) from its confluence with Sucker Creek.

Each monitoring station has been assessed prior to implementing the sampling program to ensure that samples are taken at the most suitable place(s). The inspection included the following items:

- apparent streamflow: direction and variability,
- channel configuration,
- accessability to safe sampling locations,

- the number and position of sampling locations across the stream or bridge; and
- the recommended sample collection technique(s).

This information is documented with other relevant information, e.g. photographs, weather conditions. This provides a detailed record of station characteristics, instrumentation and other information to ensure that samples are collected in the same manner and at the same location on each sampling run.

A variety of techniques can be used to collect water quality samples. These have been well documented by several Canadian agencies, Environment Canada, MOE, PLUARG, involved in hydrologic data collection. Sampling techniques employed in the sampling program are dependent on the intended use of the water sample. These techniques include:

a) grab samples
   - discrete, from one point within the stream;
   - depth integrated, at one location but over the depth of the entire water column,

b) composite samples
   - periodic, taken at regular time intervals, regardless of changes in streamflow;
   - flow proportional, taken at a frequency determined by changed in the streamflow rate.

rab samples only were collected in this study because the base-line data was aimed at developing a snapshot picture of the general water quality.

3.2 FIELD OBSERVATIONS

The field technician is responsible for logging the sample ion and any laboratory submissions, as well as observing

and documenting environmental conditions that may have a bearing on the interpretation of water quality data. These conditions include: local weather, stream status, ice conditions, water colour, odour, excessive algal growth, and fish kills. The collection of additional water samples may be warranted to enable investigation of unusual observations. The decision to analyze any "extra" samples is made by the project team and confirmed with OWMC.

3.3 FIELD QUALITY ASSURANCE

The purpose of field quality control/quality assurance protocols is as follows:

- to ensure confidence in field data collection program,
- to maintain equipment in optimal working order,
- to ensure sample container consistency, particularly regarding freedom from contamination,
- to observe measures to prevent sample contamination,
- to provide quality control checks under non-laboratory conditions, including:
    - bottle blanks
    - sample blanks
    - filter blanks, as required.

3.4 GENERAL SAMPLING ASSUMPTIONS

The report "Sampling for Water Quality" (Environment Canada, 1984) states:

"For water quality sampling sites located on a homogeneous reach of a river or stream, the collection of

depth-integrated samples in a single vertical may be adequate. For small stream a grab sample taken at the centroid of flow is usually adequate.

For sampling sites located on a nonhomogeneous reach of a river or stream, it is necessary to sample the channel cross-section at the location at a specified number of points and depths. The number and type of samples taken will depend on the width, depth, discharge, amount of suspended sediment being transported, and aquatic life present. Generally, the more points that are sampled along the cross-section, the more representative the composite sample will be. Three to five verticals are usually sufficient, and fewer are necessary for narrow and shallow streams."

Assumptions concerning the spatial distribution of contaminants in the selected watercourses, and the appropriate sampling techniques are described below.

Without prior knowledge of the specific flow conditions at a sampling station it is necessary to assume certain conditions and design the sampling program accordingly. During the sample collection program these assumptions are tested in the field and if they appear to be invalid, the collection techniques are modified accordingly.

In this program we have assumed that dissolved chemical parameters (as opposed to sediment-associated parameters) are distributed uniformly across the stream, i.e., they maintain spatial homogeneity. The collection of samples for the analysis of dissolved parameters is undertaken by "grab sampling" as described in Section 3.5.2.

To check the assumption that there is spatial homogeneity for dissolved species, conductivity measurements are taken at points across the stream and at a variety of depths. The results are

evaluated to see if there is a significant variation in the conductivity either laterally or vertically. This test is conducted twice during the data collection program, once each during high and low flows (as close to the start of data collection as possible).

Should significant lateral or vertical variability be identified the sample collection technique is modified by taking a depth-integrated sample or by using other sample compositing techniques. Use of such techniques is recorded in the field notebook.

It cannot be assumed that suspended sediment and sediment-associated parameters are uniformly distributed across the stream. The method used to collect this type of sample is known as "depth integrated sampling" as described in Section 3.5.2. For the Welland River stations it is preferable that depth integrated samples be collected at three locations spaced equidistantly across the river. This is expected to be sufficient to account for vertical and lateral variability of suspended sediment. For the Sucker Creek and 9C Creek stations (where the streams are much shallower and narrower) it is assumed that a single depth integrated sample collected at the centre of flow adequately accounts for variability in the sediment concentration.

Calibration samplings are used to check the assumption that the location and number of places selected for sampling sediment associated parameters adequately represents stream conditions. One sampling should be conducted during high flow and one during low flow (as soon as possible in the data collection program). The calibration consists of the collection of depth integrated suspended sediment samples at equally spaced intervals across the stream (10-15 samples in the case of the Welland River). These samples are analyzed for suspended sediment concentration. The results are evaluated to determine if the location and number (three) of sampling locations adequately accounts for the

distribution of suspended sediment observed during the calibration exercise. If necessary the initial sampling locations could be changed and/or their number increased until a suitable calibration is achieved.

3.5 SAMPLING TECHNIQUES

3.5.1 GENERAL CONSIDERATIONS

The following points apply to the collection of all samples.

a) All equipment and instruments are kept clean, calibrated and in good working order.

b) Repairs, re-calibrations and modifications to equipment are documented and kept on file.

c) Field technicians observe all safety regulations or guidelines.

d) Field technicians, to ensure that samples are protected from contamination and deterioration, follow the precautions in the report "Sampling for Water Quality", Section 2.3.2, as discussed in Section 3.7 of this document.

e) Field observations (unusual conditions, weather, streamflow) and field measurements (pH, dissolved oxygen, conductivity and temperature) are recorded as accurately as the measuring devices allow.

f) Samples taken by wading into a stream, are collected by entering the stream downgradient of the sampling point, walking upstream to the sample point and then collecting the sample with the sampling apparatus facing upstream during collection. This avoids contamination by sediment disturbed

in the sampling process. Sampling from bridges is done on the upstream side to enable the field technician to see whether floating material is coming downstream. This is of particular importance in the spring when floating ice may pose a safety hazard to the sampler and to the sampling equipment.

3.5.2 GRAB SAMPLES

The report "Sampling for Water Quality" (Environment Canada, 1983) describes grab samples as follows (Section 3.1.1):

> "A 'discrete' grab sample is one that is taken at a selected location, depth and time, and then is analyzed for the consitutents of interest.
>
> A 'depth-integrated' grab sample is collected over a predetermined part or the entire depth of the water column, at a selected location and time in a given body of water, and then analyzed individually for the consitutents of interest."

In shallow streams where wading is possible, discrete grab samples are collected simply by holding the sample bottle in the stream at the centroid of flow. Where wading is not possible, discrete grab samples are collected by lowering a weighted bucket sampler into the stream at the centroid of flow.

Depth integrated grab samples are collected for suspended sediment and sediment associated parameters such as total phosphorus and metals, where there is the possibility that sediment concentration is not homogeneous. A depth integrated sample is collected by lowering an open sampling apparatus to the bottom of

the stream or river and raising it to the surface at a constant rate so that the bottle is just filled with water on reaching the surface. This procedure results in the collection of a sample which approximates a theoretical depth-integrated sample (Environment Canada, 1983). Where wading is possible, depth integration may be done by hand holding the bottle or using a sampling rod which holds the bottle. In deep streams and rivers and at stations where sampling from a bridge is required, depth integrated samples are collected by using a weighted bucket sampler.

The weighted bucket water quality sampler consists of a polyethylene bucket large enough to hold a narrow mouthed one litre glass sample bottle. The bottom of the bucket is weighted. A nylon rope is used to suspend the sampler from a bridge.

3.5.3 COMPOSITE SAMPLES

A composite sample is obtained by mixing several discrete or depth integrated samples (or parts of various samples) in certain proportions (usually 1:1) to produce a single composite sample. The composite sample accounts for lateral variability in water quality across a stream. The samples to be combined are collected at several locations across a stream. The individual samples are mixed by the laboratory to produce the composite sample. The composition of the sample is recorded in the field record book.

3.5.4 SNOWPACK SAMPLING

The sampling of the snowpack accumulated on the ground is undertaken to determine the contribution of the aerial deposition of contaminants. With snowpack samples, atmospheric deposition can be ascertained separately from stream contamination. A second feature is that the melting and sublimation of snow may contribute to the concentration of contaminants in the snowpack, resulting in

a slug of contaminants moving through the stream system during major mid-winter melts and the main spring melt period.

Snowpack monitoring stations are selected to provide a representative sample, minimizing the effects of local topography. At each station the snow depth is measured along a transect and snow samples are collected for later analysis. The ideal time to sample the snowpack is just before the melt event.

On each sampling occasion a trench with vertical sides is dug through the snow to ground level along the chosen transect. The depth of snow is measured for a selection of locations along the transect.

Samples are collected by scraping a vertical section or core of the snow from the undisturbed side of the trench. The sampler ensures that the sample collected contains equal volumes of snow from all levels within the snowpack. Twigs, grass, soil and other foreign bodies are to be removed from the sample at the monitoring site to avoid having them contaminate the sample.

Snow is typically 10% water by volume, so at least 10 L of snow must be collected per litre of water analyzed. Bags are field-washed with distilled water and blanks run on distilled water stored in bags from that batch.

Samples are taken in glass containers (rinsed, foil-lid, wide mouth jars) and laboratory-grade polypropylene bags, for organic and inorganic species respectively.

All snow is transported unmelted to the laboratory, where it is stored unmelted and unpreserved until analyses are done, without addition of preservatives.

3.5.5 SEDIMENT SAMPLING

The preferred sampling technique for sediments uses a Ponar sediment sampler. With it, samples can be taken from a boat, bridge, or culvert.

The Ponar sampler consists of two quarter-cylindrical jaws hinged together at the cylinder centre. To sample, the jaws are opened and the sampler is lowered to the bottom. A closing mechanism brings the jaws together, trapping a sample.

This sample is brought to the surface and discharged to a container, and the process is repeated until sufficient sample is obtained. Although the sampler collects over a litre in volume, in many cases much of the retained volume is water rather than sediment. As well, large pebbles and organic material are removed from the sediment prior to collecting the sample.

It is generally necessary to obtain several samplers-full of material to collect sufficient sample. The samples are taken from adjacent points, so that only "surface" material is collected. Sampling at the same point would collect material from progressively deeper in the bottom.

When sufficient sample is obtained, it is mixed using a disposable spatula, and spooned into a 1 L open-mouthed jar with a Teflon®-lined lid. (The jar is previously triple-rinsed with water from a sample point).

This type of sampler is unsatisfactory for collecting samples from rubble or weedy bottoms. In such cases samples are taken using a sampling jar mounted on an extensible handle. Sampling is undertaken by scraping material laterally off the bottom. The material collected is transferred to a container and the process repeated until sediment sufficient for the analyses planned is collected. Again, large pebbles and organic matter are removed

from the sample. It is then mixed (spatula) and transferred to sample jars. This technique is less successful on hard bottom.

Where both of the above methods are unsatisfactory, material is collected by wading into the water body and scraping sediment from the bottom using a bucket. The process is repeated until enough material is obtained. Pebbles and organic matter are removed and the sample is mixed and transferred to sample jars. Use of this technique is obviously limited to relatively shallow water with a firm bottom. Since sampling in deeper water using this technique will be limited to shore areas, this method should only be used when other methods are ineffective.

The Ministry of the Environment protocols (MOE, 1981) for sediment sample handling do not call for the use of any preservation techniques other than cooling to 4°C. As most sediment analysis require only a few grams of sample, a single one-litre jar of sediment stored in a cooler chest with ice is sufficient for all analyses needed.

3.5.6 BLANK SAMPLES

One complete set of "bottle blanks" will be run at the outset of the program.

One set of field blanks will be run for each sampling event where more than two sample sets are taken.

Analyses of Bottle blanks : conductivity
TOC
TKN
total phosphorus
trace constituents (metals)
total coliform
priority pollutants

pesticides
V.O.C. (Volatile organic compounds)

Field blanks : same

3.5.7 IN-SITU MEASUREMENTS

pH Measurement

Before use each day, the pH meter is calibrated according to manufacturer's instruction using two pH buffers, one at either extreme of the expected pH values. For Southern Ontario surface waters with an expected pH over 7, this means calibrating with pH 7 and pH 10 buffers. The meter is recalibrated with pH 7 buffer before use at each set up. After obtaining pH reading(s) on the samples, the meter calibration is rechecked. If calibration is off, the meter is recalibrated and the readings repeated.

In the field book, notation is made of:

- location and sample specifics
- date
- time
- temperature, °C
- pH/ATC (automatic temperature compensation) reading

Conductivity

The meter is prepared with battery charged, electrode platinized and calibrated with 0.01N KCl to determine the cell constant. These procedures are given in the manufacturer's instructions.

The cell is triple-rinsed with distilled water before and after sample resistance measurement. Before taking a reading, the cell is rinsed three times with the sample water, both to wash out any contamination from previous samples or the carrying case, and to bring the cell to the temperature of the sample. It is very important that the cell and sample temperature be the same, and accurately known.

The cell is rinsed with distilled water after use, to prevent dissolved solids drying onto electrode surfaces.

Notations are made of:

- location specifics
- date
- time
- temperature, °C
- resistance reading (ohms)

Dissolved Oxygen

Dissolved oxygen is measured with a dissolved oxygen meter using a membrane electrode system. This electrode system consumes the oxygen which diffuses into the probe. Therefore, readings must be taken in moving water; otherwise local oxygen depletion in the probe vicinity will result in low readings. This can be arranged by agitating the probe or by testing running water.

The probe must be inspected before use to ensure that the membrane is intact and free of fouling. It must be replaced if it is suspect; instructions are provided in the manual.

Battery status must be ascertained before use (field calibration); replace if necessary.

Prior to measuring dissolved oxygen in a sample, the meter must be calibrated. The technique to be used in the field is standardization against water-saturated air. (The procedure is described in the instrument operating manual.) After calibrating, the meter probe temperature is stabilized by stirring specimens of the sample water until the temperature reading (taken with the probe) is constant. Then, with a fresh specimen, dissolved oxygen content is read while stirring the specimen with the probe. The stirring should be fast enough to continually provide fresh water at the membrane - about 0.3 m/sec. A stable reading should occur within a minute.

Avoid forming vortexes. Read temperature. Repeat with three specimens. Re-calibrate in air; if calibration has changed, re-test.

Field notations include:

- sample and location specifics
- date
- time
- temperature
- dissolved oxygen readings.

3.6 SPECIFIC SAMPLING REQUIREMENTS OF OWMC WATER QUALITY ANALYSES

The chemical and biological parameters to be analyzed on water samples collected at the Welland River, Sucker Creek and 9C Creek stations are listed in the following sections. The parameters are collected into groups which have similar bottle / preservation / collection requirements. The parameter groups are:

a) general chemistry;

b) priority pollutants and pesticides;

c) trace consituents (health and aesthetic);

d) bacteriological; and

e) field measurements.

The bottle requirements, sample preservation requirements and sample collection techniques are described for each group. Sample collection techniques are described in greater detail in Section 3.5. Actual preservative compositions and amounts are described in Section 3.7.

3.6.1 GENERAL CHEMISTRY GROUP

For the creek sample points, one sample bottle is required for the analysis of the 12 parameters in this group. The bottle is filled from the centre of flow using the "grab" technique. On the river, three samples are collected using depth integration techniques at three locations across the river width.

Bottles #1, 2, and 3 are all one litre glass bottles, aluminum foil lined cap, no preservatives, collected by the "depth integration" method at selected locations and analyzed for:

- total dissolved solids
- alkalinity
- major cations
- major anions
- total organic carbon
- nitrate
- nitrite
- phosphorus
- suspended sediment
- total phosphorus

NOTE: Only one determination will be undertaken by the laboratory for each parameter. The laboratory composites the samples collected at each location into a single sample.

In addition this group includes:

Bottle #4 is a 250 mL glass bottle, aluminum foil lined cap, preserved with sulphuric acid, collected by the grab method at the center of the flow and analyzed for:

- ammonia
- TKN

3.6.2 PRIORITY POLLUTANTS AND PESTICIDES GROUP

A total of six to eight sample bottles are required for the parameters in this group. All of the samples should be collected at the centre of flow using the "grab" sample technique.

Bottles #5, 6, 7, 8, 9 and 10 are all one litre glass bottles with aluminum foil lined caps, and no preservatives, to be analyzed for priority pollutants (base/neutral extractable, acid extractable) and pesticides. The priority pollutants include those specified elsewhere in this report.

Six bottles are required to provide duplicates for one site out of each set; the other sites require only four bottles.

Bottles #11 and 12 are glass vials with a septum caps and no preservatives, to be analyzed for volatile organics. The septum vials must be filled such that no air remains in the vial when it is sealed (no 'head-space').

3.6.3 TRACE CONSTITUENTS (HEALTH AND AESTHETIC) GROUP

A total of five sample bottles are collected for the analysis of parameters in this group. Since many metals are sediment-associated, the samples are collected by depth integration techniques at the centre of flow. Analysis of total sample (water + sediment) will be undertaken accordingly.

Bottle #13 is a one litre glass bottle, foil lined cap, preserved with NaOH and analyzed for:

cyanides

Bottle #14 is a one litre glass bottle, foil lined cap, preserved with zinc acetate and sodium bicarbonate and analyzed for:

sulphides

Bottle #15 is a 250 ml glass bottle, foil lined cap, preserved with phosphoric acid and copper sulphate and analyzed for:

phenols

Bottle #16 is a 250 ml glass bottle, foil lined cap, preserved with $K_2Cr_2O_7/HNO_3$ and analyzed for:

mercury

Bottle #17 is a 500 ml polystyrene/polyethylene bottle, preserved with HNO_3 and analyzed for:

lead
cadmium
chromium
arsenic
iron
manganese
aluminum
copper
zinc

3.6.4 BACTERIOLOGICAL GROUP

Three sample bottles are required for the collection of samples in this group. These samples will be collected by means of the "grab" sampling technique at the centre of flow in the stream.

Bottle #18 and 19 are 250 mL glass bacteriological sample bottles, preserved with thiosulphate and analyzed for:

bacteriological parameters

- background
- total coliforms
- fecal coliforms
- fecal streptococci

Bottle #20 is a 250 ml glass bottle, aluminum foil lined cap, no preservative and analyzed for:

BOD

The sample bottle requirements for the collection and preservation of samples for analysis of all parameters are summarized on the following table.

Specimen	Bottle(s)	Preservatives	Parameters
1.	3-1 L glass	Ø	"General chemistry" 3 locations; phosphorus and suspended solids
3.	6-1 L glass	Ø	priority pollutants and pesticides
4.	2-septum-cap vials	Ø	volatile organics
2.	1-250 mL glass	H_2SO_4	ammonia, TKN
5.	1-1 L glass	NaOH	cyanide
6.	1-1 L glass	$Zn(OAc)_2$ Na_2CO_3	sulphide

Specimen	Bottle(s)	Preservatives	Parameters
7.	1-250 mL glass	H_3PO_4 $CuSO_4$	phenols
8.	1-250 mL glass	HNO_3 $K_2Cr_2O_7$	mercury
9.	1-500 mL bottle polystyrene	HNO_3	"metals" group
10.	2-250 mL bacterio-logical bottles	Thiosulphate	bacteriological testing
11.	1-250 ml glass	Ø	BOD

3.6.5 FIELD MEASUREMENT GROUP

Parameters in this group will be measured in the field. The method of taking field measurement is described in Section 3.5.7. The parameters are:

- pH,
- conductivity,
- dissolved oxygen, and
- temperature.

3.7 SAMPLE HANDLING

3.7.1 PRESERVATION

General Protocols:

General Procedures

Rinse bottle and cap three times with sample water. Fill to bottle shoulder. Segregate and refrigerate bottles requiring no

preservative immediately. Segregate bottles requiring preservative systematically; when all samples have been taken, add all preservatives in the same order each time. Preferably, preserve samples requiring one unique preservative first; e.g. for ammonia, add sulphuric acid; for cyanide, add NaOH; for phenols, add H_3PO_4 and $CuSO_4$ solutions. As each bottle is preserved, cap it and segregate it from those not yet treated. Where a number of bottles need the same preservative, do them in a batch; where more than one preservative is needed, add any that are common to other samples first, then add the unique one last. For example: for a bottle to be tested for "metals" and another for mercury: add nitric acid to both bottles; discard pipette tip; cap "metals" bottle; add chromate to mercury bottle; discard pipette tip; cap mercury bottle.

Bacteriological Samples

Do not rinse sample bottle with sample water; fill bottle, leaving 2" airspace, and cap. Refrigerate immediately. (4°C; ice packs in freezer chest.)

Pipette Handling

Preservatives are added to bottles using a pipette with disposable tips, to be used only once. After use, place discarded pipette tips in a polyethylene garbage bag, to be carried to each site.

The garbage is not to be carried with instruments or reagents. Rinse and discard on return to base.

When using Eppendorf pipette with disposable tips: fill the pipette tip slowly, to avoid aspirating preservative into the pipette pumping chamber. This can damage the pipette internally, affecting its volumetric calibration, but, more importantly, can also contaminate subsequent samples.

Preservative Concentration using Eppendorf pipette

Adjusting the Eppendorf pipette individually for each preservative dose is cumbersome and likely to introduce errors in dosage. Instead, it is convenient to set the pipette for about its mid-range, and adjust the preservative concentration to given the required preservative quantity for the smallest sample bottle. As bottle sizes used are 1/4 L, 1/2 L or 1 L, this gives minimum pipette manipulation. The concentration and quantity of preservatives used in this assessment are shown below.

Preservative Contamination

Phosphoric acid and copper sulfate solutions for preserving "phenols" samples are not to be stored in plastic containers, since phenolic preservatives are commonly present in plastics. Glass, with aluminum foil-lined cap, is preferred.

Preservative materials must be certified free of significant concentrations of the substances being analyzed for.

Caps

Generally, with glass bottles, use of aluminum foil-lined caps is specified. Where these are not available, cut pieces of aluminum foil to cover the bottle mouth, and screw the cap securely over the foil to form a seal. A square of foil slightly larger than the bottle neck diameter is satisfactory.

It is necessary to carry spare bottles and caps as this technique occassionally results in breakage.

This technique is not necessary for bacteriological samples, or "metals" samples taken in polystyrene bottles. The caps as provided are satisfactory.

PRESERVATIVES USED

Analysis for:	Volume	Preservative	mL	Concentration
1. "Metals" group	500 mL, plastic	HNO_3	1	1:1 in water
2. Mercury	250 mL glass	HNO_3 $K_2Cr_2O_7$	2 0.5	1:1 in water saturated
3. Cyanides	500 mL glass	NaOH	1.0	25%
4. Sulphides	1 L glass	$Zn(OAc)_2$ Na_2CO_3	2 3 max. (to precipitate)	2N 1.2 N (5%)
5. Phenols	250 mL glass	H_3PO_4 $CuSO_4$	0.5 1.0	1:1 in water 20%
6. Ammonia, Total Kjeldahl nitrogen	250 mL glass	H_2SO_4	0.5	50%

Transportation

It is important for some parameters that analyses be conducted as quickly as possible, at least within 24 hours. The sampling program includes sample collection, packing and refrigeration on the day of the sampling, and delivery by the sampling crew to the laboratory(ies) the same afternoon or the next morning. All samples are stored in coolers packed with ice immediately after they are taken.

3.7.2 SAMPLE IDENTIFICATION

The Sampling Schedule includes nine dates, four locations. The sampling protocol requires that we take up to 20 bottles of water containing some 12 L from each site, depending on the analyses to be done.

Each sample bottle is identified on a label by a unique number (see below), with a notation indicating the preservative used and the analysis to be performed. An identical label will be inserted in the field analyses book (see below). With this label, other data will be entered to identify sample-specific conditions, including date, time and location. Factors such as weather, water appearance, level, odour, color, etc., will also be entered in the book.

Label

M.M. Dillon Limited

Date _____

Sample # _____

Bottle Type _____

Preserved with _____

Analyze for _____

Receiving Laboratory _____

Sampled by _____

Field Book Page (Typical)

Label (1)	**Date Filtration** **Time:** **Site**	**Conditions**
Label (2)	**Site:**	
Label (3)	**Site:**	

Dillon will retain the information correlating the sample number and the site in the field book. This will reduce the potential for prejudice on the part of the analytical laboratory. The "analyses" code on the labels will refer to a key in the possession of the laboratory as noted below. All samples will be refrigerated immediately; where other preservatives are used, they are noted.

LABELLING SUMMARY

Label Description	Analytical Parameters	Preservative(s)
"Metals	lead) chromium) cadmium) arsenic) iron) manganese) aluminum) copper) zinc)	Nitric acid
"Mercury"	mercury	Nitric acid/dichromate
"Cyanide"	cyanide	Sodium hydroxide
"Sulphide"	sulphide	Zinc acetate/sodium carbonate
"Pesticides"	the spectrum of pesticides for which drinking water standards apply, plus others used locally	None
"Priority Pollutants"	base/neutral and acid extractable pollutants	None
"Volatile Organics"	volatile pollutants from the EPA priority list	None
"Bacteriological"	background count) total coliform) fecal coliform) fecal streptococci)	None
"BOD"	BOD	
"Ammonia"	ammonia) TKN) total phosphorus)	Sulphuric acid
"General Chemistry"	total dissolved solids) turbidity) alkalinity) major cations) major anions) total organic carbon) nitrate)	None

The sampling log book will contain:

- a copy of each sample label including blanks;
- identification of sampling procedures;
- identification of non-routine procedures or practices;
- field tests run and results;
- identification of field conditions : date
  : time
  : temperature
  : "weather"

3.7.3 CHAIN OF CUSTODY PROCESS

Documentation of samples consists of the following:

1. Two copies of a set of adhesive labels, preprinted with sample numbers, date, bottle description, preservative and analysis. One set is to be applied to the sample bottles as the samples are taken in the field; the other is applied to the page in the field notebook where field conditions and analyses are recorded. Both are initialed by the sampler.

2. Three copies of the sample description sheet, containing the same information as the labels are prepared for each laboratory. All are initialed by the sampler.

   One is retained by the sampler; two are given to the sample receiver (at the laboratory). The receiver initials one set and returns it (by mail) to the sampler, and retains one for his own records.

CHAPTER 4
QUALITY ASSURANCE AND QUALITY CONTROL

4.1 INTRODUCTION

Laboratory methods for determination of water quality parameters have been selected to ensure reliability of results with reasonable cost. In this way, the maximum amount of useful data can be obtained with given financial resources. As a general principle, the methods used have been validated for the range of contaminant concentrations expected, both by comparison with other standard methods and through acceptance by regulatory authorities, such as the Ministry of the Environment.

In addition, consistency of results is monitored through intra-laboratory quality control checks and procedures. Where required, procedural modifications are instituted to keep the analytical quality at the desired standard. The method of attaining these quality maintenance goals is generally dependent on the principles on which the individual analytic method is based.

For example, anion/cation balances can be used as an indicator of precision for analysis of anions and cations; other methods require routine comparison with standard materials.

The methods used for each analysis and the checks on their accuracy and precision are described in detail in Appendix 'B'.

4.2 QUALITY ASSURANCE PROCEDURES

4.2.1 GENERAL

While it is not, in principle, possible to ensure that all data produced by an analytical program are of "high quality", a number of procedures may be introduced that will indicate, with high probability, the bounds of expected error in a set of analyses. The application of these procedures is considered here to be a quality control function for the data; the development and monitoring of quality control is considered the quality assurance function.

For an analysis, error may be introduced through sample contamination, systematic or random contamination of laboratory equipment, equipment precision, operator inconsistency, and the like. Some controllable or predictable factors can be accounted for; calibration and operator training and monitoring are examples of how to accomplish this. Such programs are of necessity in place in any commercial laboratory. Where necessary for this program, they are extended and documented in detail. Such procedures are described in Appendix 'B'.

As external checks on the quality control within the laboratory, this program uses two techniques specific to it.

First, blank samples prepared in the field are submitted to the laboratory. At least one-tenth of the samples submitted are blanks. These serve two functions. Any contamination introduced during field operations is detected by the laboratory. Such contamination is then considered in interpreting the analyses of non-blank samples. In addition, the blanks aid in detecting analytical bias at low contaminant levels, and results from other non-blank samples can be interpreted taking this into consideration. (These two error types are distinguished by rechecking analyses with laboratory blanks.) An extension of this practice is that of submitting split, or duplicate, samples to the laboratory. Differences in analysis greater than the normal measurement precision indicate a problem in analysis and remedial action is included.

The second quality assurance technique is to supply duplicate samples to a different laboratory. Again, at least one-tenth of samples taken are duplicated. Differences between analysis outside a predictable tolerance range would indicate a problem with one or the other laboratory. Naturally, it is imperative that the second laboratory be capable of as high quality analytical procedures as the first. Where results do not match, investigation of methods, analyst techniques, and standards is required.

Using these techniques, both intra-laboratory and inter-laboratory consistency can be documented. This does not eliminate possibility of error; however, it does specifically identify the range of values which an analytical result could represent with known probability. The methodological tools used to estimate analytical reliability are discussed below.

4.2.2 ANALYTICAL SYSTEM FUNCTIONS AFFECTING DATA QUALITY

The following functions are obtained from the American Society for Testing Materials (ASTM, 1984).

a) Assurance that the System is in Control

In practice, this is confirmed by running a significant number of analyses on materials of known composition. A reliable estimate of the standard deviation of the analysis is obtained. The system is not in control at the 95% confidence limit if it produces "unexpected" results more than once in every 20 analyses; it is not in control at the 99.7% confidence limit if unexpected results occur more than three times in a thousand.

b) Criteria of Detection

The criterion of detection is the minimum quantity of a material which must be observed before it can be stated with any certainty that the substance is present and not recorded simply as an analytical artifact. At a significance level of 5%, the criterion of detection = 1.64 x the analysis standard deviation. A result greater than this has a 95% probability of meaning the material is actually present.

c) The Analytical Detection Limit

This value is double the criterion of detection. A result greater than this indicates that a subsequent reanalysis would be unlikely (95%) to produce a result lower than the criterion of detection.

d) Procedures Documentation

All procedures with any potential for affecting analytical results are documented; in addition, data handling procedures are documented. The handling of low-concentraton results ("less than" reports) and duplicates is made consistent with the precision requirements for other results.

e) Control Charts

The variation in system results are charted versus time. When the limits of variability, at an acceptable confidence level, are exceeded, the system is considered out of control. These charts create a systematic method for determining the acceptability of analytical results. If in the analysis, over a given time period, of standards of known concentration, or unknown duplicate samples, the analytical results fall within the control limits (± three standard deviations as discussed below) the analytical system is considered to be in control. All analyses conducted in that time period are considered of acceptable quality. If the charted results, described above, fall outside the control limits, all analytical results obtained in that time period are questioned. Methods for generating control charts for the analysis of known standards and duplicate unknowns are shown below.

f) Analytical Variability

Estimating population standard deviation is required where a large bank of duplicate results is not available. This procedure is suitable.

i) 5 or 6 duplicate analyses are conducted on samples of similar concentration.

ii) 40 to 50 duplicate standards and samples are run; both in-run and between-run analyses may be required.

iii) Population standard deviation is estimated as 1/1.128 (average difference between duplicates).

iv) This standard deviation is used as a preliminary estimate for preparing control charts with ± 3 times standard deviation as control limits.

v) The initial estimates of standard deviation are updated by pooling the initial estimate with new data from ongoing analysis of duplicates or standards. This requires that no substantial changes in standard deviation occur.

vi) Significance of changes in analytical variabilty may be tested by comparing the ratio of the variances from two time periods of concern with values on an F-table. This will indicate whether they belong to the same statistical population or whether some change has occurred. If changes are suspected, the system requires review.

vii) If the standard deviation changes new control limits are set at ± 3 standard deviations.

g) Duplicate Standards

Duplicate analyses are needed to determine analytical recovery and degree and direction of bias. Control limits are set as known concentration ± 3 standard deviations.

h) Analysis of Unknown Duplicates

This produces another set of data indicating whether system performance is in or out of control. Control charts are set up, indicating a range of ± 3.686 system standard deviations as control limits.

i) Spiked Sample Analysis

Both the recovery performance of the system and biases high or low are indicated by these analyses. Control limits are centred around the estimate of bias.

j) Standard and Duplicate Analysis Frequency

These should be done at least once per ten analyses, or once per batch, whichever is greater. They should be conducted during analytical series or between runs, depending on whether intra- or inter-run variation is being tested.

REFERENCES

1. Taylor, John K., 1985. 'What is Quality Assurance?' in Quality Assurance for Environmental Measurements ASTM STP 867. American Society for Testing and Materials (1985).

2. M. M. Dillon Limited, 1969. Hydraulic Procedures Manual prepared for the Government of Trinidad.

3. Environment Canada, 1983. Water Quality Branch, Inland Waters Directorate. Sampling For Water Quality.

4. American Society for Testing and Materials, (ASTM), 1984. Annual Book of ASTM Standards, Water and Environmental Technology, Volume 11.01 - Water, pp. 7-15.

5. Ontario Ministry of the Environment, (MOE), Laboratory Services Branch, 1976. Quality Control and Data Evaluation Procedures, Section I - Analytical Reproducibility.

6. Ontario Ministry of the Environment, Laboratory Services Branch, 1981. Outlines of Analytical Methods.

APPENDIX 'A'

FIELD FORMS - STREAMFLOW GAUGING

STREAMFLOW GAUGING RECORD

Gauging No. _____

Date: _____ Project No.: _____ Names: _____

_____

Flow Rate: _____ m^3/sec. or L/sec.

Location: _____

_____

_____

Meter: _____ Model: _____ No.: _____

Pivot/Propellor No.: _____ Staff Gauge _____ m

Weather: _____

Stream Width: _____ m. Max. Depth: _____ m. Water Temp.: _____ °C

Clarity: _____ Water Source: _____

Description of Bottom: _____

_____

Comments: _____

_____

_____

_____

Sketch:

Gartner Lee Associates Limited

STREAMFLOW GAUGING SHEET

Gauging No.: _____ Project No.: _____ Date: _____

Station (m)	Depth of Water (m)	Measuring Point	Distance of Meter Above Bed (m)	Revolutions	Time (sec.)	$N = \frac{R}{T}$	Velocity at Point (m/sec.)	$\bar{V}$ in Vertical Profile (m/sec.)	Area (m^2) of Section	$\bar{V}$ in Section (m/sec.)	Q (m^3/sec.) or (L/sec.)

If D < 0.3 m MP = 0.6 from (0.4 from bed)
If D > 0.3 m MP = 0.2, 0.8

If D > 1.0 m MP = 0.2, 0.6, 0.8

APPENDIX 'B'

DETAILED ANALYTICAL AND LABORATORY QUALITY CONTROL PROCEDURES

APPENDIX B
DETAILED ANALYTICAL AND LABORATORY QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

B.1 INTRODUCTION

Quality assurance and quality control (QA/QC) protocols for laboratories conducting chemical and bacteriological analysis describe the analytical procedures used by the laboratory to conduct a specific analysis and the quality control procedures implemented by the laboratory to ensure the accuracy and precision of a given set of analytical results. As discussed in the body of this protocol document laboratory QA/QC is conducted in two distinct manners:

intralaboratory QA/QC; and
interlaboratory QA/QC.

Intralaboratory QA/QC procedures are procedures undertaken within each of the laboratories working on this OWMC surface water quality study. These procedures are conducted to ensure the day-to-day quality of the analyses being done. Intralaboratory QA/QC procedures include such activities as:

- using only well trained personnel for analysis;

- documenting analytical procedures;

- purchasing analytical standards and chemicals from reputable suppliers;

- maintaining a rigorous laboratory and glassware cleanliness program;

- conducting a high level management review of all analytical data prior to release to the client to ensure data quality.

All of the above are quality assurance activities (as described in the Introduction to the Protocol Document).

Intralaboratory quality control procedures involve the analysis of:

- known standard samples;
- duplicate samples and;
- laboratory reagent blanks.

These 'quality control samples' are analyzed in the same manner as unknown samples. The laboratories plot the results of the 'quality control sample' analyses onto daily Control Charts. These Control Charts are then used to check the accuracy and precision of the analytical instrument or method being used. If questionable 'quality control sample' results are obtained in an analytical run then all analytical results obtained for unknown samples during that run are also questioned and repeated if necessary.

Interlaboratory quality assurance/quality control is undertaken by having two or more laboratories analyze replicate unknown samples using their own analytical techniques. The analytical results generated by the different laboratories should be comparable to within an allowable error which will be assessed individually for specific chemical or bacteriological parameters. Interlaboratory analytical results which are widely different will be flagged by Dillon and the analysis will be repeated if required. For the purposes of this OWMC surface water quality assessment, approximately 10% of the water samples collected will be analyzed in duplicate for all parameters, by two different laboratories.

The laboratory analysis for the 1986 OWMC surface water quality assessment was carried out by four laboratories:

- Barringer Magenta Limited;
- Mann Testing Laboratories Limited;
- Standard Biological Laboratories; and
- Ontario Research Foundation.

Barringer Magenta is carrying out 'general chemistry', 'metals', mercury, cyanide, sulphide and ammonia analyses for the entire study. Barringer is also conducting the interlaboratory quality control analysis of 'volatile organics', 'priority pollutants', and 'pesticides'. Mann Testing Laboratories is analyzing all samples for 'volatile organics', 'priority pollutants' and pesticides'. Standard Biological Laboratories is conducting the analysis of 'bacteriological' parameters. Ontario Research Foundation is undertaking the interlaboratory quality control analysis of 'general chemistry', 'metals', mercury, cyanide, sulphide, ammonia and 'bacteriological' parameters. A more detailed description of the specific 'general chemistry',

'metals', 'volatile organics', 'priority pollutants', 'pesticides' and 'bacteriological' parameters being analyzed in this study is shown in Section 3.7 of this Protocol Document.

The detailed intralaboratory quality assurance and quality control activities and protocols that are being undertaken by each of the four laboratories is presented following. The detailed protocols describe:

- analytical procedures being used;
- general laboratory QA/QC; and
- QA/QC procedures specific to an analytical method or instrumentation.

Analytical procedures have been detailed only when they vary from standard methods for conducting that analysis. Where standard methods are used the reference source of the method or procedure is documented.

A fifth laboratory (Zenon Environmental Laboratories) has carried out the priority organic and pesticide analysis on quality assurance samples from November 1986 to date.

B2. QA/QC IN BACTERIOLOGICAL ANALYSIS

Bacteriological analysis is conducted by allowing bacteriological growth, under controlled conditions, onto a culture medium which is specific to an individual bacteria. The cultured bacteria are then counted using a microscope. Because these procedures involve the culturing or growth of a bacteria, it is impossible to

develop and analyze standard samples of a bacterial colony. As a result, QA/QC methods in bacteriological laboratories differ from those in chemical laboratories. Bacteriological laboratories do analyze quality control duplicate and blank samples. As well, they strictly control the preparation, storage and growth promotion capabilities of the specific culture media. Therefore, the majority of the QA/QC data presented by Standard Biological Laboratories and Ontario Research Foundation is related to the preparation of culture media and the evaluation of bacterial growth promotion on the prepared medium.

APPENDIX B.3

QUALITY ASSURANCE/QUALITY CONTROL PROTOCOLS

BARRINGER MAGENTA LIMITED

W.D. #6381C

APPENDIX B.3.1

ANALYTICAL PROTOCOLS USED IN THE OWMC WATER QUALITY SURVEY

Prepared for:
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M2N 6H5

Prepared by:
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May 1986

1. INTRODUCTION

Barringer Magenta Limited is currently providing analytical services to M.M. Dillon Limited with respect to a background water quality survey being performed for the Ontario Waste Management Corporation (OWMC). This document provides a brief description and summary of the analytical protocols used for the analyses of both inorganic and organic parameters for the above mentioned water quality survey.

This protocol is not designed to be a regurgitation of the analytical methods manual and, as a result, the analytical methods used are described in a very brief tabular form. In addition to the methodologies, the quality control and quality assurance protocols are also described. Once again, a general description is provided along with more detailed information as it pertains to this particular program. For the most part, the procedures used are taken from well documented sources and any in-house modifications are documented accordingly.

2. ANALYTICAL METHODOLOGIES

The analytical methods used for the water analyses provided to M.M. Dillon under this contract are summarized in Table 1. It should be noted that, for the most part, the methods are identical to those given in the listed references. If the size of sample aliquots taken or the proportions of reagents used were chosen in order to make the analyses more convenient based on the present facilities and capabilities of the laboratory then these were not considered to be major modifications to the method. In the cases where significant differences from the published methodologies are apparent, these have been noted accordingly.

Tables 2 through 5 give the detection levels that were reported for this program. In some cases, such as the ion chromatography and ICAP analyses, all of the parameters which are reportable as part of these packages have been listed. Since these services are offered as a package, results for all of the parameters are given at no additional charge.

A similar situation exists with the organic packages as shown in Table 5. Once again, these represent a single analysis with a number of different components monitored during the process. These particular packages were originally designed after the U.S. E.P.A. protocols and have been expanded to include some parameters not currently on the priority pollutant list.

TABLE 1

Summary of Analytical Methods

Parameter	Reference[1.]	Modified ?[2.]	Description
pH	SM-423 MOE-PC1 EPA1-150.1	No	- electrode - purchased buffer stds
Alkalinity	SM-403 MOE-AB1 EPA1-310.1		- fixed endpoint titration - to pH 4.5 - standardized H_2SO_4 (0.002-0.01 N depending upon levels expected) - standardization using NaOH and $KHC_8H_4O_4$
Conductance	SM-205 MOE-CI1 EPA1-120.1	Yes	* - employing flow-through conductivity detector of a Dionex Model 2110i Ion Chromatograph - standardized with KCl solutions - plot reading against normality of KCl - re-plot normality of KCl against conductance - Dionex detector provides temperature compensated readings
Turbidity	SM-214 MOE-TC1 EPA1-180.1	No	- uses Turner Fluorimeter - calibrated with solutions of Hydrazine Sulphate/Hexamethylene Tetramine solutions - 400-600 nm response zone
Cations	SM-305 MOE-MD54 EPA1-200.7	No	- A.R.L. Model QA-137 Inductively Coupled Argon Plasma Emission Spectrophotometer - calibration standards prepared from purchased solutions - computerized correction for spectral interferences

TABLE 1 (Continued)

Summary of Analytical Methods

Parameter	Reference[1.]	Modified ?[2.]	Description
Anions	SM-429 MOE-CD18, NB1, SH12 EPA1-300.0	No	- Dionex Model 2110i Ion Chromatograph - Eluent: 0.0024 M Na_2CO_3 0.003 M $NaHCO_3$ - Columns: AS4A + A64 (guard column) - Detector: conductivity - Standards: prepared from salts
T.O.C.	Manufacturers Literature SM-505B MOE-CB20 EPA1-415.1	No	- subcontracted to Beak Consultants Ltd. - infra-red detection - Beckman system
Ammonia-N	SM-417G MOE-NA1 EPA1-350.1	No	- automated phenate colourimetric procedure - standards prepared from NH_4Cl - Technicon AA-I system
TKN	SM-420B	No	- colourimetry - automated phenate colourimetric procedure - $H_2SO_4/K_2S_2O_8/TiO_2$ digestion - standards prepared from NH_4Cl
Total P	SM-424F MOE-PF22 EPA1-365.4	No	- colourimetry (automated) - ascorbic acid reduction - $H_2SO_4/K_2S_2O_8$ digestion - standards prepared from K_2HPO_4
Metals	SM-304 MOE-MD21 EPA1-213.2, 218.2, 239.2	No	- graphite furnace atomic absorption Pb 283.3 nm Cd 228.8 nm Cr 357.9 nm - standards (see cations)

TABLE 1 (Continued)

Summary of Analytical Methods

Parameter	Reference[1.]	Modified ?[2.]	Description
Metals (Contd.)	SM-303E MOE-AD1 EPA1-245.2	No	- automated hydride generation atomic absorption (heated quartz tube) As 193.7 nm - standards (see cations)
	SM-303F MOE-MC11 EPA1-245.2	No	- cold vapour atomic absorption - $HNO_3/H_2SO_4/KMnO_4$ digestion - Laboratory Data Control Model 1205 Mercury Monitor (dual channel with gold trap in reference channel) - $SnCl_2$ reduction Hg 303.2 nm - standards from $HgCl_2$
Cyanide	SM-412D MOE-CJ1 EPA1-335.2	Yes	- acidification, distillation - trapping in NaOh * - colourimetric with pyridine/pyrazolone reagent - absorbance at 620 nm - standards from KCN
Organics			
Volatiles	EPA-624	Yes	- GC/MS - Finnigan 1020B * - 60 m SPB-1 wide-bore capillary column - CDS-320 Purge and Trap concentrator - OWA data processing system
Base-Neutrals) Acid Extractables)	EPA2-625	No	- GC/MS - Finnigan 1020B - 30 m DB-1 fused silica cap. column - Varian on-column capillary injector - OWA data processing system

TABLE 1 (Continued)

Summary of Analytical Methods

Parameter	Reference[1.]	Modified ?[2.]	Description
Organochlorine Pesticides/PCB's	EPA2-608 MOE-OB4	No	- GC/ECD - Model 4500 Varian GC equipped with an on-column capillary injector - 15 m DB-1 fused silica capillary column - Ni-63 electron capture detector
Phenols	SM-510B MOE-PD1 EPA1-420.1	No	- distillation - colour development with - 4-aminoantipyrine - chloroform extraction - absorbance measured at 460 nm - Phenol standards used
Sulphide	SM-427C MOE-SI18 EPA1-376.2	No	- Colourimetry with ferric chloride and dimethyl-p-phenylenediamine (methylene blue method) - standards from Na_2S, standardized by iodometric titration

1. SM = Standard Methods for the Examination of Water and Wastewater (16th Ed.), APHA-AWWA-WPCF (1985).

   MOE = Handbook of Analytical Methods, Ontario Ministry of the Environment (1983).

   EPA1 = Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency (revised 1983)

   EPA2 = Guidelines Establishing Test Procedures for the Analysisj of Pollutants Under the Clean Water Act; Final Rule and Interim Final Rule and Proposed Rule, Federal Register: Environmental Protection Agency, 40 CFR Part 136 (1984).

2. The methods used are similar to those listed in the references with the possible exception of the volumes taken or reagent proportions used. If significant deviations from the published methods are used, this is indicated here and the modification is flagged (*) in the "Description" column.

TABLE 2

Analytical Detection Limits

(mg/l unless otherwise noted)

General Chemistry:	
pH	± 0.01 pH units
Alkalinity	0.2 mg $CaCO_3$/l
Conductance	1.0 umhos/cm
Turbidity	1.0 NTU
Total Dissolved Solids	1.0 mg/l
Cations	(see Table 3)
Anions	(see Table 4)
Total Organic Carbon	0.5 mg/l
Nutrients:	
NO_3^- and NO_2^-	(see Table 4)
Ammonia-N	0.05
TKN	0.05
Total P	0.01
Trace Constituents (Health):	
Pb	0.001
Cd	0.0001
Cr	0.001
As	0.001
Hg	0.00005
CN^-	0.004
$S^=$	0.001
Trace Constituents (Aesthetic):	
Fe	See Table 3
Mn	See Table 3
Al	See Table 3
Cu	See Table 3
Zn	See Table 3
Phenols	0.001
Organic Constituents:	
(see Table 5)	(see Table 5)

TABLE 3

I.C.A.P. Multi-element Package Detection Limits (mg/l)

Ag	0.0005	Cu	0.001	Pb	0.005
Al	0.005	Fe	0.001	Si	0.05
B	0.005	K	0.01	Sr	0.0001
Ba	0.0005	Mg	0.001	Th	0.005
Be	0.00005	Mn	0.001	Ti	0.0005
Ca	0.005	Mo	0.02	V	0.0005
Cd	0.001	Na	0.1	Sn	0.005
Co	0.005	Ni	0.005	Zr	0.002
Cr	0.001	P	0.05		

TABLE 4

Ion Chromatography Package Detection Limits (mg/l)

F^-	0.005
Cl^-	0.01
NO_2^-	0.02
$PO_4^=$	0.1
Br^-	0.05
NO_3^-	0.05
$SO_4^=$	0.05

TABLE 5

Summary of Organics Analytical Packages and Detection Limits

51 VOLATILE ORGANICS PACKAGE

COMPOUND	D.L.(ug/l)	COMPOUND	D.L.(ug/l)
Acrolein	5.0	trans-1,2-Dichloroethene	1.0
Acrylonitrile	5.0	Dichloromethane	1.0
Benzene	1.0	1,2-Dichloropropane	1.0
Bromobenzene	1.0	cis-1,3-Dichloropropene	2.0
1-Bromo-2-chloroethane	1.0	trans-1,3-Dichloropropene	2.0
Bromodichloromethane	1.0	2,3-Dichloropropene	2.0
Bromoform	1.0	1,4-Dioxane	500.0
Bromomethane	5.0	Ethylbenzene	1.0
Carbon Disulphide	5.0	Hexachlorobutadiene	1.0
Carbon Tetrachloride	1.0	Hexachloroethane	1.0
Chlorobenzene	1.0	Pentachloroethane	1.0
Chloroethane	5.0	Styrene	1.0
2-Cloroethylvinylether	2.0	1,1,2,2-Tetrachloroethane	1.0
Chloroform	1.0	Tetrachloroethene	1.0
Chloromethane	5.0	1,1,2,3-Tetrachloropropene	2.0
3-Chloropropene	2.0	1,2,4-Trichlorobenzene	1.0
Dibromochloromethane	1.0	1,1,1-Trichloroethane	1.0
1,2-Dibromoethane	1.0	1,1,2-Trichloroethane	1.0
Dichloroacetonitrile	2.0	Trichloroethene	1.0
1,2-Dichlorobenzene	1.0	Trichlorofluoromethane	2.0
1,3-Dichlorobenzene	1.0	1,1,2-Trifluorotrichloroethane	1.0
1,4-Dichlorobenzene	1.0	Toluene	1.0
Dichlorodifluoromethane	5.0	Vinyl Chloride	5.0
1,1-Dichloroethane	1.0	m-Xylene/p-Xylene	1.0
1,2-Dichloroethane	1.0	o-Xylene	1.0
1,1-Dichloroethene	1.0		

TABLE 5 (Continued)

Summary of Organics Analytical Packages and Detection Limits

Priority Pollutant - Base Neutrals (46 Compounds)

Compound	Limit of Detection, ug/l
Acenapthene	10
Acenaphthylene	10
Anthracene	10
Benzo(a)anthracene	10
Benzo(b)fluoranthene	10
Benzo(k)fluoranthene	10
Benzo(a)pyrene	10
Benzo(g,h,i)perylene	25
Benzidine	10
Bis(2-chloroethyl)ether	10
Bis(2-chloroethoxy)methane	10
Bis(2-ethylhexyl)phthalate	10
Bis(2-chloroisopropyl)ether	10
4-Bromophenylphenylether	10
Butyl Benzyl Pthalate	10
2-Chloronapthalene	10
4-Chlorophenylphenylether	10
Chrysene	10
Dibenzo(a,h)anthracene	25
Di-n-butylphthalate	10
1,3-Dichlorobenzene	10
1,4-Dichlorobenzene	10
1,2-Dichlorobenzene	10
3,3-Dichlorobenzidine	10
Diethyl Phthalete	10
Dimethyl Phthalate	10
2,4-Dinitrotoluene	10
2,6-Dinitrotoluene	10
Dioctyl Phthalate	10
1,2-Diphenylhydrazine	10
Fluoranthene	10
Fluorene	10
Hexachlorobenzene	10
Hexachlorobutadiene	10
Hexachloroethane	10
Hexachlorocyclopentadiene	10
Indeno(1,2,3-c,d)pyrene	25
Isophorone	10
Naphthalene	10
N-Nitrosodimethylamine	10
N-Nitrosodi-n-propylamine	10
N-Nitrosodiphenylamine	10
Phenanthrene	10
Pyrene	10
1,2,4-Trichlorobenzene	10
Nitrobenzene	10

TABLE 5 (Continued)

Summary of Organics Analytical Packages and Detection Limits

Priority Pollutants - Acids (11 Compounds)

Compound	Limit of Detection, ug/l
4-Chloro-3-methylphenol	25
2-Chlorophenol	25
2,4-Dichlorophenol	25
2,4-Dimethylphenol	25
2,4-Dinitrophenol	100
2-Methyl-4,6-dinitrophenol	100
2-Nitrophenol	25
4-Nitrophenol	25
Pentachlorophenol	25
Phenol	25
2,4,6-Trichlorophenol	25

Priority Pollutants - Pesticides (25 Compounds)

Compound	Limit of Detection, ug/l
Aldrin	.003
a-BHC	.002
b-BHC	.004
d-BHC	.004
g-BHC	.002
Chlorodane	.04
4,4'-DDD	.012
4,4'-DDE	.006
4,4'-DDT	.016
Dieldrin	.006
Endosulfan I	.005
Endosulfan II	.01
Endosulfan Sulfate	.03
Endrin	.009
Endrin Aldehyde	.023
Heptachlor	.002
Heptachlor Epoxide	.004
Toxaphene	.40
PCB-1016	.04
PCB-1221	.10
PCB-1232	.10
PCB-1242	.05
PCB-1248	.08
PCB-1254	.08
PCB-1260	.15

TABLE 6

Reference Standards Used in O.W.M.C. Survey

Standard	Certified Parameters
EPA - Minerals	pH, Alkalinity, F^-, Cl^-, $SO_4^=$, Conductance, TOS
EPA - Nutrients	NH_3-N, TKN, Total P, NO_3^-, PO_4^{-3}
EPA - Phenols	Phenols
EPA - Cyanide	Cyanide
EPA - Trace Metals - I	ICAP, AA, As, Hg
EPA - Volatile Organics) EPA - Non-Halogenated or Aromatic Purgeables)	Volatile Organics
EPA - GC/MS Base Neutrals I, II & III	Base/Neutral Extractables
EPA - GC/MS Acids	Acid Extractables
EPA - Chlorinated Hydrocarbon Pesticides I, II & III	Organochlorine Pesticides/PCB's
EPA - Herbicides	Phenoxy Acid Herbicides

3. QUALITY ASSURANCE AND QUALITY CONTROL

In any analytical program it is vital that proper quality assurance and quality control practices be followed in order to establish credibility in the final results obtained. These practices must include both good technique and implementation as well as thorough documentation of the procedures employed. A generalized summary of the QA/QC procedures routinely employed at Barringer are presented in Appendix I. This excerpt was taken from a Manual of Standard Operating Procedures for the laboratory operations at Barringer.

In programs involving water quality analyses, the inclusion of blanks and sample replicates is a fairly easy procedure. The inclusion of reference standards, however, becomes a somewhat more difficult issue. Up until recently, the onus was on the laboratory to prepare standard solutions which could be used for this purpose, the only criteria being that their source was independent from the standards used for calibration purposes. In this way it was hoped that an independent mechanism would exist for verifying the accuracy of the calibration standards and as a monitor on recovery of various extraction processes. More recently, however, various organizations have been producing concentrates which are meant to be used for quality control and water analysis programs. These include the National Bureau of Standards, the U.S. Environmental Protection Agency and Environmental Resources Associates. Barringer has been employing the standard provided by the U.S. E.P.A. for many of its water quality tests. A list of the standards used in this program is presented in Table 6.

Control charting is a regular quanlity control procedure at Barringer. Control charts are established to monitor overall precision and accuracy of the analytical techniques used. In

order to simplify any subsequent presentation requirements it was decided that control charts be set-up specifically for this program and kept separate from the normal lab control charts. In this way the specific program can be monitored and not lost in the routine analytical work performed by the laboratory. Samples of these control charts have been presented along with the quality assurance description in Appendix I.

4. REFERENCES

More detailed information on the procedures outlined in this manual can be found in the following references.

A. Quality Control References

1. United States Environmental Protection Agency, HANDBOOK FOR ANALYTICAL QUALITY CONTROL IN WATER AND WASTEWATER LABORATORIES, Ref. EPA-600/4-79-019 (March 1979)

2. Ontario Ministry of the Environment, THE WATER QUALITY LABORATORIES, DATA QUALITY SUMMARY, D.E. King and P. Fellin (1975)

3. Ontario Ministry of the Environment, QUALITY CONTROL AND DATA EVALUATION PROCEDURES, D.E. King (1976)

4. Ontario Ministry of the Environment, PRINCIPLES OF CONTROL CHARTING, D.E. King (1984)

B. Analytical Methods Manuals

1. U.S. Environmental Protection Agency, METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES, EPA Ref. 600/4-79-020 (May 1979)

2. Environment Canada, ANALYTICAL METHODS MANUAL (1979), Inland Waters Directorate, Water Quality Branch, Ottawa, Ontario (Aug. 1979)

3. Ontario Ministry of the Environment, HANDBOOK OF ANALYTICAL METHODS FOR ENVIRONMENTAL SAMPLES, Laboratory Services and Applied Research Branch, Rexdale, Ontario (December 1983)

4. A.P.H.A., A.W.W.A., W.P.C.F., STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, 16th Ed., (1985)

5. U.S. Environmental Protection Agency, METHODS FOR ORGANIC CHEMICAL ANALYSIS OF MUNICIPAL AND INDUSTRIAL WASTEWATER, Ref. EPA-600/4-82-057 (July 1982)

6. U.S. Environmental Protection Agency, MANUAL OF CHEMICAL METHODS FOR PESTICIDES AND DEVICES, A.O.A.C., Ref. ISBN 0-935584-23-4 (July 1976)

7. American Society for Testing and Materials, ANNUAL BOOK OF A.S.T.M. STANDARDS, PART 31, WATERS (1979)

8. American Society for Testing and Materials, ANNUAL BOOK OF A.S.T.M. STANDARDS, Vol. 4.08, SOIL AND ROCKS: BUILDING STONES (1984)

9. Perkin-Elmer, ANALYTICAL METHODS FOR ATOMIC ABSORPTION SPECTROPHOTOMETRY (Jan. 1982)

10. Rudolf Bock, A HANDBOOK OF DECOMPOSITION METHODS IN ANALYTICAL CHEMISTRY, Halsted Press (1979)

11. A.O.A.C., OFFICIAL METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS (1975)

APPENDIX B.3.2

Quality Assurance/Quality Control

QUALITY ASSURANCE AND QUALITY CONTROL PRACTICES

GENERAL CONCEPTS

The purpose of a QA/QC program is to ensure consistency of data quality and accurancy in the analytical results. It must provide a routine method of monitoring the analytical process and provide a quick feedback to the analyst as to the degree of control. The then main determinants of control are background levels, precision and accuracy. These are monitored routinely by the insertion into the analytical scheme of blanks, replicates and reference standards, respectively.

With the monitoring of these three facets of the analytical process, documentation is also essential to provide a time-based monitor of the quality of the various analytical methods. This can be accomplished by centralized recording of the data obtained, and by the use of control charts. These would provide a realistic summary of analytical performance over time, enabling accurate determination of confidence and control limits. If these limits prove to be wider than is considered acceptable, it provides feedback on methods which are in need of re-evaluation and modification. It is essential that everyone involved in analytical work be aware of the importance of QA/QC protocols and adhere strictly to the accepted procedures.

BACKGROUND MONITORING

During an analytical process, backgrounds can be introduced via a number of different processes. If glassware has not been cleaned properly, contamination may be introduced from these sources. This contamination would be inconsistent and

sporadic. Another source of contamination could be from the reagents used in the analytical process. Backgrounds due to reagent contaminants would be much more consistent, showing up as a constant background in all samples.

In order to determine whether one of the former situations exist, reagent blanks are inserted in each work order at a frequency of one reagent blank for every 30 samples analyzed. It should be noted that this is not simply a calibration blank but a sample which is taken through every digestion, extraction or colour development phase of the analytical method. The only thing omitted is the sample aliquot. Reagent contaminations are easily discovered by analysis of these blanks, especially if a number of them have been included in a work order. An example is the blank observed when a poor grade of potassium permangante is used for digestions of sediments and sludges for mercury analysis. Analysis of several blanks would give a constant background reading with a very tight precision. This may represent a mercuric impurity in the reagent and should be corrected for as long as the precision is very close and the sample levels are significantly higher (at least 5x).

If some blanks give large readings and others give none, a sporadic contamination has probably occurred. This type of contamination cannot be corrected for and the analysis of that batch of samples should be terminated, the glassware rewashed and the entire analysis repeated.

MONITORING OF ANALYTICAL PRECISION

Analytical precision is simply the reproduceability of the procedure being followed. The usual method of monitoring this precision is the analysis of some samples in duplicate. This is done at a frequency of one replicate for every 30 samples

analyzed. The sample repeated is usually the one immediately following the previous blank. For example, if sample #10 was a blank, sample #20 would be a repeat of sample #11. As in the case of the reagent blank analyses, this is not simply a re-analysis of the same sample solution but involves taking a separate sample aliquot and putting it through the entire analytical process. One point to note is that poor precision observed by this process is not necessarily just an indication of a poor analysis approach. Poor precision can also occur if an inhomogenous sample is involved. In this case, the analytical precision may be excellent but, in effect, the sample aliquots being taken for analysis are not identical. This can sometimes be discerned for large work orders if the precision for a number of analyses of a reference standard show markedly better precision than that observed in the sample replicates. If this is suspected, the only recourse is to re-prepare the sample by homogenization, if feasible, and re-analyze it.

MONITORING ACCURACY

In order to measure the degree of accuracy in any analytical method several factors must be taken into account. The calibration standards used must be properly prepared, the analytical procedure must not cause any loss of analyte, interferences must be properly eliminated or accounted for and analyte recoveries must be quantitative.

To monitor calibration standard accuracy, it is necessary to have an independent lab control solution that has sufficient stability to be used over a period of time. All calibration standards should be prepared from primary standard grade reagents but the preparation process must be constantly

monitored. The first step to be taken when a new series of standard solutions is prepared is to compare the new standards to the old ones. If a discrepancy occurs, the old standards may be the problem. Subsequent to this comparison, therefore, a reference standard solution should be analyzed against the new standards and the value obtained compared to the certified or accepted value. If the value obtained does not lie within a given acceptance window, usually less than a 5% deviation from the certified value, the standards should be re-prepared. Purchased standards, such as those available for GC/MS priority pollutant work, should also be evaluated by a similar procedure before their implementation for calibration purposes.

To measure losses of analyte as a result of the analytical process, reference standards are inserted at a frequency of one standard for every 30 samples analyzed. This is inserted in every thirtieth sample position. The reference standards should be chosen so as to match the sample matrix as closely as possible, and to have an analyte level close to that expected for the samples. If the results obtained are not within the specific acceptance windows (see Section 4.5), the procedure should be reviewed, the problem corrected and the sample re-analyzed.

New reference materials are constantly being introduced as supplies of the older one are depleted. Some of the standards to be used for our routine analyses are given in Table 4.

Interferences could also be monitored in a similar manner by analyzing either synthetic or purchased interference check samples. This type of standard is especially useful for I.C.A.P. analysis where corrections for spectral interferences are performed as a routine part of the analytical process. These standards usually contain low levels of analytes with

fairly substantial excesses of known interferents.

CONTROL CHARTS

Control charts are used to monitor the long-term data quality for analysis of reference standards to enable a quick visual assessment of the degree of control for a particular analytical run. They are basically a plot of analyte recovery as a function of time. Whenever a given standard is analyzed with a work order, its result is plotted on the appropriate control chart. Over a period of time, the analytical precision can be viewed directly on the chart. Control limits can be set up and acceptance criteria established. An example of a typical control chart is given in Figure 7. If the result obtained for a given standard run lies outside the given control limits, the sequence of samples associated with that standard run must immediately be scheduled for re-analysis.

Each lab supervisor should keep a binder with all of the control charts for all standards used routinely and it should be kept as a integral part of the QA/QC process. Quality control is a vital part of the laboratory operation and the practices described here should be adhered to strictly in order to ensure the client of accurate data and to keep the laboratory's reputation held in high regard.

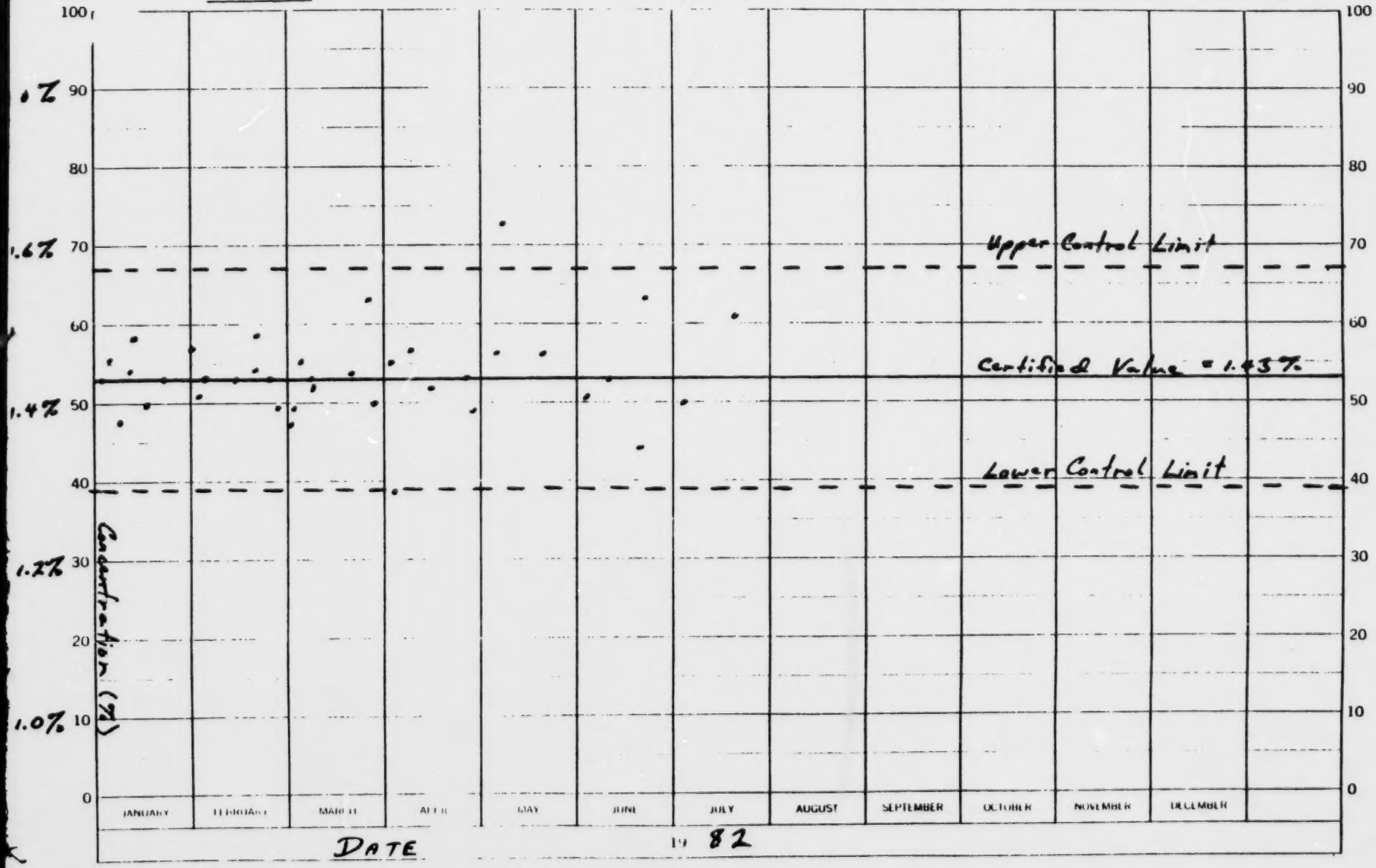
TABLE 4

REFERENCE STANDARDS MOST COMMONLY USED

Matrix	Standard Source
Rock Analysis:	SY-2 (Canmet) SY-3 (Canmet) MRG-1 (Canmet)
Soil/Sediment Analysis:	Estuarian Sediment (SRM 1646-NBS) River Sediment (SRM 1645-NBS) SO-1 to SO-4 (Canmet) GXR-1 to GXR-6 (U.S.G.S.) Deer Lake #1, 2 (in-house)
Vegetation Analysis:	Citrus Leaves (SRM 1572-NBS) Pine Needles (SRM 1575-NBS) Orchard Leaves (SRM 1571-NBS) Tomato Leaves (SRM 1573-NBS)
Tissue Analysis:	Bovine Liver (SRM 1577a-NBS) Oyster Tissue (SRM 1566-NBS)
Water Analysis:	WASTEWATER SET (E.R.A.) TRACE ELEMENTS IN WATER (SRM 1643a-NBS) Purchased Metals Stock Solutions (Canlab, BDH, etc.)
Miscellaneous:	TRACE ELEMENTS IN COAL-BITUMINOUS (SRM 1632a-NBS) TRACE ELEMENTS IN COAL-SUBBITUMINOUS (SRM 1635-NBS) TRACE ELEMENTS IN COAL FLY ASH (SRM 1633a-NBS) STAINLESS STEEL (SRM 101f-NBS)

K+E 1 YEAR BY MONTHS X 100 DIVISIONS KEUFFEL & ESSER CO. 46 3170

FIGURE 7: EXAMPLE OF A REFERENCE STANDARD CONTROL CHART FOR ELEMENT X IN STANDARD Y



APPENDIX B.4

GENERAL QUALITY ASSURANCE/QUALITY CONTROL PROTOCOLS
MANN TESTING LABORATORIES

Appendix B.4.1

QUALITY ASSURANCE/QUALITY CONTROL PROGRAM FOR ORGANIC & INORGANIC ANALYSIS

The quality assurance program incorporated in Mann Testing Laboratories is to ensure the accuracy of the monitoring and measuring methods, and the continuing high validity of analytical data. This program is also designed to assist both management and clients in the assessment of the accuracy and precision of data generated, and to ensure the analytical work will withstand legal scrutiny in regulatory action.

According to the American Chemical Society[1] a quality assurance program should include the following elements and these parameters are endorsed by Mann Testing Laboratories Ltd.:

1. Maintenance of skilled personnel, written and validated methods, and properly constructed, equipped, and maintained laboratory facilities.
2. Provision of representative samples and controls.
3. Use of high-quality glassware, solvents and other testing materials.
4. Calibration, adjustment, and maintenance of equipment.
5. Use of control samples and standard samples, with proper records.
6. Directly observing the performance of certain critical tests.
7. Review and critique of results.
8. Tests of internal and external proficiency testing.
9. Use of replicate samples.
10. Comparison of replicate results with other laboratories.
11. Response to user complaints.
12. The monitoring of results.
13. Correction of departures from standards of quality.

The following sections describe the integral parts of our QA/QC program.

1.0 CHAIN OF CUSTODY

Mann Testing Laboratories have established a chain of custody procedure which documents the history of the samples from collection to final analysis. A responsible party is identified to act as sample custodian at each stage of sample handling operation and verify the necessary data entered onto the sample custody record (Table I & II).

This procedure ensures sample integrity, prevents mix-ups, and detects unauthorized tampering. With this secure and complete documentation of sample history, potential litigation can further be supported.

2.0 QUALITY CONTROL AUDITS

A quality control audit is an assessment activity to evaluate the data produced by the laboratory's analytical system. This is accomplished by carrying out intra and inter-laboratory check sample analysis.

2.1 Interlaboratory Check Sample Programs

Mann Testing Laboratories have participated in the following external quality control programs:

* National Water Research Institute - Interlaboratory Quality Control Study on the analysis of total PCB's and trace metals - Environment Canada

Table 1

MANN TESTING LABORATORIES LTD.
5550 McADAM ROAD, MISSISSAUGA, ONT L4Z 1P1
TELEPHONE (416) 890 2555 • TELEX 06-960496

CHAIN OF CUSTODY FORM

Containers prepared by _____ Sealed by _____

SHIP TO Tag Number _____

Company _____ Attention _____

Address _____ Telephone _____

_____ Postal Code _____

Received in good condition by

_____ _____
(Please Print Name) Signature

Date _____ Time _____ Tag Number _____

CONTENTS

SAMPLES	REMARKS	SAMPLES	REMARKS

Samples collected and sealed by _____
(Please Print Name)

Tag Number _____ Signature _____

Relinquished to:
CHAIN OF CUSTODY CHRONICLE

1 I have received these materials in good condition from the above person.
Please Print Name _____ Signature _____
Date _____ Time _____ Remarks _____

2 I have received these materials in good condition from the above person.
Please Print Name _____ Signature _____
Date _____ Time _____ Remarks _____

3 I have received these materials in good condition from the above person.
Please Print Name _____ Signature _____
Date _____ Time _____ Remarks _____

MANN TESTING USE ONLY

Opened by _____ Date _____ Time _____

Tag Number _____ Analysed by _____

Condition _____

Table 2

MANN TESTING LABORATORIES LTD.

LABORATORY CHAIN-OF-CUSTODY RECORD

Project: _____ W.O.# _____

Sample Type: _____

Sample Preparation For: _____

Sample Identifcation	Extracted By	Date	Analysed By	Date

VERIFIED BY: _____

* Collaborative study on the analysis of trace pollutants extracted from drinking water - Health & Welfare Canada

* Federal Interdepartmental Committee on Pesticides (FICP) check sample program - Agriculture Canada

* International Joint Commission interlaboratory study on the analysis of % Lipid Pesticides and PCB's in fish homogenates - I.J.C.

* Environmental Protection Service - Organic Round Robin for Priority Pollutants by GC/MS - Waste Water Technology Centre - CCIW

* National Water Research Institute - National Interlaboratory Quality Control study on polynuclear aromatic analysis - Environment Canada

* International Joint Commission Data Quality Work Group - Intercomparison study on Toxic Organics

* Upper Great Lakes Connecting Channel Quality Control study on PCB's, chlorobenzenes, organochlorines, PAH's and metals

* National Interlaboratory Quality Control Program on Trace Metals

These programs compare Mann Testing Laboratory's performance to that of other laboratories. Results are analysed statistically by the agencies responsible for the QC studies. Most of these programs are ongoing.

2.2 Interlaboratory Performance Audits

Reference materials obtained from US EPA or the quality assurance section of Environment Canada and spiked samples are used on a regular basis to determine the performance of analysis. These check samples are treated as blind samples and processed through routine operations. The results are summarized in the audit report. A corrective action is taken immediately when biased results are detected.

3.0 INSTRUMENT CALIBRATION

Instrument calibration standards pertaining to specific detectors are prepared and introduced into the analytical instrument prior to analysis. Based on the data obtained over a period of time when the process is in control, measurements are collected which represent the reading of the instrument when they are in good running conditions.

Once these measurements have been obtained, a control chart can be established and the means and standard deviation is calculated. Warning limits are marked at +2 and -2 standard deviations wheras the rejection points are set at +3 and -3 standard deviations.

These control charts are then used to provide graphic assessment of accuracy and precision of each analysis and instant detection of erroneous data.

4.0 SAMPLE ANALYSIS

The quality control procedures used in sample analysis provides means for detecting an out-of-control situation and speed up remedial action. The procedures adopted by Mann Testing Laboratories include the following:

* Standard sample preparation and analytical methods such as those developed by EPA, NIOSH, AHPA, and AOAC etc. will be used.
* Blanks (travel & reagent etc.) will be analysed to provide

information on background and positive interferences introduced during sample collection and handling.

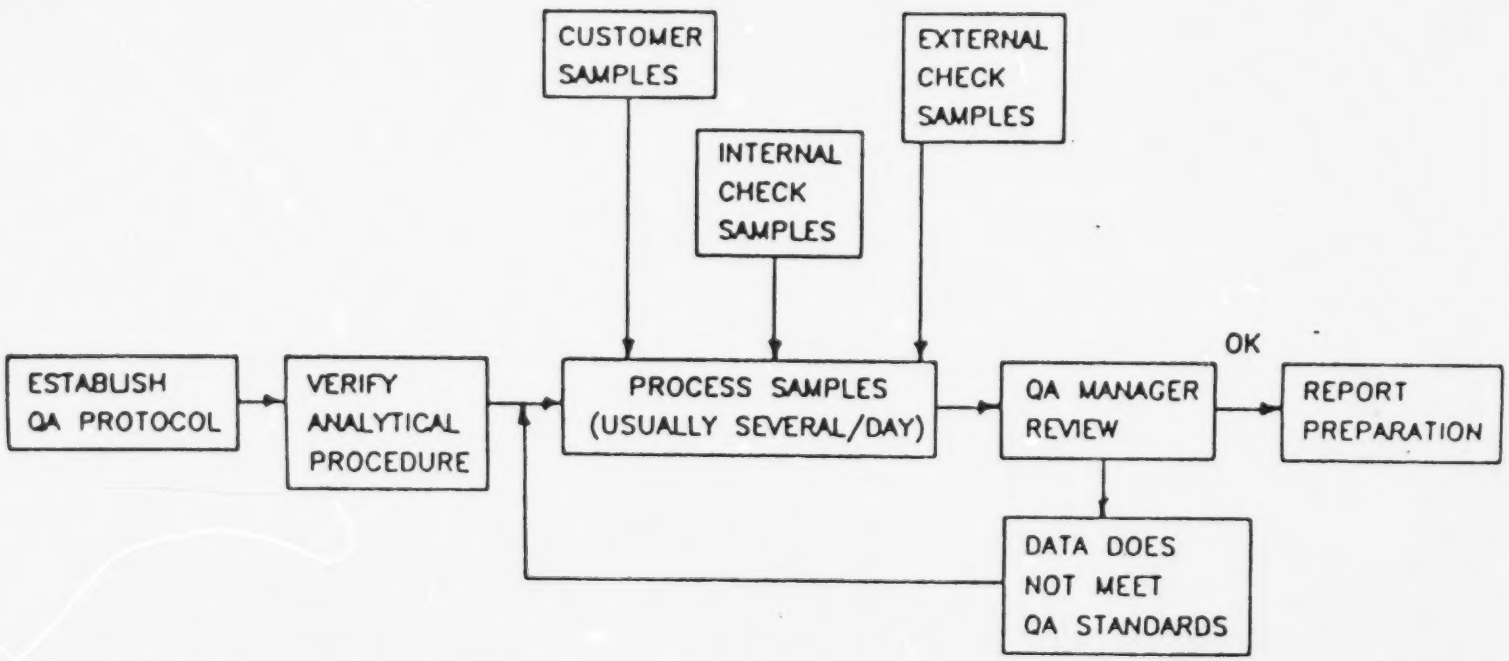
* Duplicate as well as split samples will be run to provide data on the precision of the analytical system. A minimum of 10% of all samples submitted for each type of analysis will be run in duplicate and/or split.
* Laboratory spikes will be done on a representative selection of the split samples. The laboratory spikes will provide recovery data for each type of analysis.
* Standard reference material obtained from government and commercial sources will be analysed along side routine samples and the results used to check the accuracy of analytical procedures.
* Internal standards will be spiked into the samples where applicable to provide information on the accuracy of the results.
* Statistical procedures will be utilized to evaluate the data and to establish acceptable limits.
* All pertinent information on sample analysis, instrument performance and calibration will be documented.

5.0 RECORDS MAINTENANCE

Records are an important component in the quality assurance program. They provide detailed documented evidence on the entire sample analysis and all relevant QC activities. At Mann Testing, complete records on sample analysis, quality control charts, logs of all QC works and calibration will be maintained

for legal needs. In addition, the records will be reviewed by the quality control officer in the laboratory to ensure the necessary QC procedures have been followed. A schematic diagram of the quality control procedure is depicted in Figure 1.

Figure 1



MANN TESTING LABORATORIES LTD.

COSTING

I) Analysis

Parameter	Method of Analysis	Price
General Chemistry		
TDS	wet/gravimetric	$12.50
alkalinity	wet/titrimetric	12.00
major cations (Na,K,Mg,Ca)	FAAS	28.00
major anions (F,Cl,Br,SO_4,PO_4)	IC	pkg.(*)
Nutrients		
nitrate	IC	pkg.(*)
nitrite	IC	40.00(*)
total phosphorous	wet/IC	24.00
Trace Constituents		
lead	GFAAS	15.00
cadmium	GFAAS	15.00
chromium	GFAAS	15.00
arsenic	hydride-AAS	15.00
mercury	CVAAS	15.00
Trace Constituents		
iron	wet/FAAS	8.00
manganese	wet/FAAS	8.00
aluminum	wet/FAAS	8.00
copper	wet/FAAS	8.00
zinc	wet/FAAS	8.00
Trace Organics		
Priority Pollutants		
volatiles	GC/MS	300.00
acid/BN extractables	GC/MS	660.00
Pesticides	GC-ECD	180.00

Notes:

1) Prices given are to meet detection limits specified. Changes to the D.L.'s may result in changes to the cost of some parameters.

2) Prices include QA/QC work detailed separately.

3) Prices include supply of containers, labels and preservatives.

Methodology Code

FAAS	-	flame atomic absorption spectrometry
GFAAS	-	graphite furnace atomic absorption
hydride-AAS	-	hydride flameless atomic absorption
CVAAS	-	cold vapour flameless atomic absorption
IC	-	ion chromatography (suppressed)
GC/MS	-	gas chromatography/mass spectrometry
GC-ECD	-	gas chromatography - electron capture detector

II) Stand-By Charges

As requested, provision has been made for maintaining staff 'on-call' in the event that their use may be necessary. The cost of such a service will be based on a per hourly rate of $45.00.

III) QA/QC Documentation

We estimate that the QA/QC documentation required to support our data submission as specified in your letter of January 16, 1986, will be $1000.00.

APPENDIX B.4.2

ANALYSIS SPECIFIC QUALITY ASSURANCE/QUALITY CONTROL PROTOCOLS

MANN TESTING LABORATORIES

VOLATILE ANALYSIS - WATER SAMPLES

Sampling Preparation - Collection and Handling

Water samples for purgeable organics were collected in 50 ml capacity amber glass bottles equipped with Tuf-Bond discs and screw caps with a syringe access hole in the centre. The bottles had been previously cleaned and heated at 200°C for at least 4 hours, purged with nitrogen and sealed with PTFE coated silicone and open top caps prior to transportation to the sampling sites.

The bottles were filled to slight overflow, then sealed so that no air bubble was present in the sample. They were immediately returned to Mann Testing Labs and stored at 4°C until analysed.

Preparation of Standard Solutions

Stock standard solutions were prepared by injecting appropriate amounts of each pollutant into 25 ml of glass distilled methanol (Burdick and Jackson) in reactiflasks fitted with Minnert valves (Chromatographic Specialties Ltd.) which provide complete protection and easy access via a hypodermic needle. The resulting concentration of 1 mg/ml was further diluted to give methanolic solutions of 400 ug/ml, 40 ug/ml and 4 ug/ml for each component. Gaseous standards were prepared in a similar manner by injecting the gaseous compound from a 10 ml gas tight syringe into a pre-weighed reactiflask filled with 25 ml of methanol. The syringe needle was slightly above the ethanol meniscus while injecting, hence enabling the gas to dissolve rapidly into the

methanol. The flask was re-weighed again to determine the amount in the solution.

Aqueous composite standards were prepared by injecting appropriate aliquots of methanolic standard in 250 ml sample bottles filled with purified water.

The relative retention times (RRT) were compared to that of the internal standard, deuterated chlorobenzene (RRT = 1.00) which eluted close to the middle of the chromatogram. Detection limits were determined by purging aqueous composite standard mixture at various concentrations.

Instrumentation

Analysis of volatile organics in water was conducted using a UNACON 780B automatic concentrator (Envirochem Inc., Kemblesville, P.A.). This instrument utilized the technique developed by Bellar and Lichtenberg for the isolation and concentration of volatiles for chromatographic analysis. In general, this process involved gas stripping of the sample and adsorption of the organic compounds on a sorbent trap followed by thermal desorption and analysis by gas chromatography or gas chromatography/mass spectrometry.

The sample purging assembly included a sparger vial with a side port which was equipped with an open top screw cap and Tuf-Bond septum. A 30 ml vial was used to obtain detection limits as reported. Sample was transferred to the vial through a transfer line by pressurizing the sample bottle which was inverted and clamped on the side of the instrument. The transfer

line was constructed of 1/16" teflon tubing with two Luer Lock connectors at each end. Two 17-gauge needles were used to puncture the septa of both the bottle and the side port.

Prior to the start of the analysis, the sparger vial was purged with helium for 5 minutes by rotating the valve to "Trap-Out" mode. In this position, any contaminants that were present in the sparger vial were purged out of the system without entering the trap. An appropriate aliquot of the water was then transferred to the sparger and purged for 15 minutes at the "Trap-In" mode. The trap was heat desorbed and the organics backflushed into the second trap. When this transfer process was completed, the second trap was again heated, releasing all adsorbed organics into the capillary GC/MS system for identification and quantification.

The MDL (Method Detection Limit) listed in the volatile section is the limit that the compound can be identified and quantified in the sample matrix using the purge & trap GC/MS method.

QA/QC

Prior to sample analysis reference standards were analyzed to determine the instrument response for standards of known levels. Instrument blanks were then analyzed to determine the extent of any instrument contamination. Travelling blanks for each set of samples were analyzed to measure any possible background contamination caused by the sample container. At ten sample intervals duplicate samples were analyzed to monitor the analytical reproducibility.

TABLE I

RETENTION DATA, % RECOVERY & CHARACTERISTIC IONS OF THE VOLATILE ORGANICS

Compound	RRT	% RECOVERY	PRIMARY ION (m/e)	SECONDARY IONS (m/e)
Dichlorodifluoromethane	0.477	99.8	85	87
Chloromethane	0.486	100.3	50	52
Vinyl Chloride	0.495	106.2	62	64
Bromomethane	0.511	105.0	94	96
Chloroethane	0.516	91.9	64	96
Trichlorofluoromethane	0.545	101.6	101	103
1,1-Dichloroethylene	0.568	98.6	61	63,96
Dichloromethane	0.571	92.7	49	84
t-1,2-Dichloroethylene	0.608	92.3	61	63,96
1,1-Dichloroethane	0.614	97.2	63	65,83
Chloroform	0.661	90.5	83	85,87
1,2-Dichloroethane	0.690	80.3	62	64,98
1,1,1-Trichloroethane	0.707	102.5	97	61,99
Benzene	0.729	97.5	78	51,77
Carbon Tetrachloride	0.737	97.6	117	119,121
1,2-Dichloropropane	0.769	91.2	63	62,76
Bromodichloromethane	0.779	94.2	83	82,129
Trichloroethylene	0.782	101.2	95	130
1,3-Dichloropropene(Z)	0.827	90.8	75	110
1,3-Dichloropropene(E)	0.857	78.9	75	110
1,1,2-Trichloroethane	0.866	71.1	83	97
Toluene	0.888	91.4	91	92
Dibromochloromethane	0.914	79.7	129	127
Tetrachloroethylene	0.960	126.2	129	166,131
Chlorobenzene	1.003	92.7	112	77,114
Ethyl Benzene	1.026	93.9	91	106
m,p-Xylenes	1.038	95.4	91	105,106
Bromoform	1.042	52.5	173	171,175
o-Xylene	1.067	88.3	91	105,106
1,1,2,2-Tetrachloroethane	1.066	45.0	83	85
1,3-Dichlorobenzene	1.199	86.4	146	148,111
1,4-Dichlorobenzene	1.204	86.7	146	148,111
1,2-Dichlorobenzene	1.231	85.4	146	148,111
Acrolein	0.528	22.1	56	55
Acrylonitrile	0.551	7.9	53	52
Pentane	0.512	82.7	43	42,57
Dimethyl Sulphide	0.518	80.2	47	62,45
Methylethylketone	0.591	8.8	43	72
Hexane	0.622	84.3	57	41,43
Heptane	0.787	97.8	43	57,71
4-Methyl-2-pentanone	0.823	26.6	43	58,85

TABLE I(cont'd)

REPRODUCIBILITY OF SELECTED VOLATILE ORGANICS USING PURGE & TRAP SYSTEM

Compound	Ion (m/e)	Peak Intensity Run#1	Run#2	Run#3	SDV	% C.V.
Dichlorodifluoromethane	85	41408	46016	47488	3171.9	7.1
Chloromethane	50	19840	18560	19072	644.3	3.4
Vinyl Chloride	62	81664	83072	89728	4307.2	5.1
Bromomethane	94	49536	52608	66048	8781.8	15.7
Chloroethane	64	39872	35648	47616	6069.7	14.8
Trichlorofluoromethane	101	100992	93568	123008	15310.9	14.5
1,1-Dichloroethylene	61	22848	21600	20832	1017.5	4.7
Dichloromethane	84	24096	20512	20896	1967.8	9.0
t-1,2-Dichloroethylene	61	32032	28064	27776	2378.4	8.1
1,1-Dichloroethane	63	54272	48064	50496	3128.2	6.1
Chloroform	83	55168	52160	46528	4385.9	8.6
1,2-Dichloroethane	62	31904	31296	35840	2467.8	7.5
1,1,1-Trichloroethane	97	48256	50432	51008	1451.5	2.9
Benzene	78	99200	93184	105984	6403.8	6.4
Carbon Tetrachloride	117	37824	37248	40896	1961.2	5.1
1,2-Dichloropropane	63	21984	20768	24064	1666.8	7.5
Bromodichloromethane	83	48640	51136	51136	1441.1	2.9
Trichloroethylene	130	46208	43072	46208	1810.6	4.0
1,3-Dichloropropene(Z)	75	38272	38848	40320	1056.2	2.7
1,3-Dichloropropene(E)	75	28704	25696	30400	2382.3	8.4
1,1,2-Trichloroethane	97	36672	32416	38848	3271.6	9.1
Toluene	91	145408	140544	145664	2885.0	2.0
Dibromochloromethane	129	47808	43200	52096	4449.0	9.3
Tetrachloroethylene	129	66176	64448	66816	1224.9	1.9
Chlorobenzene	112	104960	101248	96640	4168.0	4.1
Ethyl Benzene	91	139008	124032	135168	7778.6	5.9
m,p-Xylenes	91	111104	99584	117120	8910.8	8.2
Bromoform	173	34240	30336	30528	2200.6	6.9
o-Xylene	91	121856	113152	124032	5757.2	4.8
1,1,2,2-Tetrachloroethane	83	37312	33984	31072	3122.3	9.2
1,3-Dichlorobenzene	146	99584	88192	101504	7195.8	7.5
1,4-Dichlorobenzene	146	114304	101248	118400	8957.6	8.0
1,2-Dichlorobenzene	146	94976	86144	94464	4958.0	5.4
Acrolein	56	3452	2636	2872	419.9	14.1
Acrylonitrile	53	6024	4592	4984	740.0	14.2
Pentane	43	82048	71808	71296	6065.3	8.1
Dimethyl Sulphide	62	64384	56896	60544	3744.4	6.2
Methylethylketone	43	17024	23136	20757	3080.9	15.2
Hexane	57	66944	73472	84608	8931.6	11.9
Heptane	43	117248	123648	125824	4458.0	3.6
4-Methyl-2-pentanone	43	53440	64448	51904	6842.1	12.1

TABLE I (cont'd)

GC/MS
% RECOVERY REPRODUCIBILITY
5 ppb level

	% Recovery Run #1	% Recovery Run #2	% Recovery Run #3	Ave. % Recovery	SDV
Dichlorodifluoromethane	93.6	101.6	104.1	99.8	5.5
Chloromethane	88.7	99.1	113.2	100.3	12.3
Vinyl Chloride	92.1	112.1	114.4	106.2	12.3
Bromomethane	95.4	108.6	111.0	105.0	8.4
Chloroethane	93.8	91.9	90.0	91.9	1.9
Trichlorofluoromethane	105.6	95.8	103.3	101.6	5.1
1,1-Dichloroethylene	97.1	99.1	99.7	98.6	1.4
Dichloromethane	96.2	93.1	88.7	92.7	3.8
t-1,2-Dichloroethylene	88.1	91.8	96.9	92.3	4.4
1,1-Dichloroethane	93.2	103.1	95.4	97.2	5.2
Chloroform	97.4	92.1	82.1	90.5	7.8
1,2-Dichloroethane	75.0	73.5	92.5	80.3	10.6
1,1,1-Trichloroethane	100.8	101.5	105.3	102.5	2.4
Benzene	96.3	101.2	95.0	97.5	3.3
Carbon Tetrachloride	95.5	94.0	103.2	97.6	4.9
1,2-Dichloropropane	90.0	85.1	98.6	91.2	6.8
Bromodichloromethane	99.0	92.0	91.6	94.2	4.2
Trichloroethylene	103.9	97.5	102.1	101.2	3.3
1,3-Dichloropropene(Z)	87.3	88.6	96.4	90.8	4.9
1,3-Dichloropropene(E)	81.4	72.9	82.5	78.9	5.3
1,1,2-Trichloroethane	73.7	65.1	74.6	71.1	5.2
Toluene	93.7	90.6	89.9	91.4	2.0
Dibromochloromethane	81.2	73.3	84.7	79.7	5.8
Tetrachloroethylene	127.3	125.2	126.1	126.2	1.1
Chlorobenzene	96.4	92.9	88.7	92.7	3.9
Ethyl Benzene	95.8	92.5	93.5	93.9	1.7
m,p-Xylenes	98.1	91.5	96.6	95.4	3.5
Bromoform	56.7	50.2	50.5	52.5	3.7
o-Xylene	90.5	89.7	84.7	88.3	3.1
1,1,2,2-Tetrachloroethane	46.6	42.5	46.0	45.0	2.2
1,3-Dichlorobenzene	86.4	88.4	84.3	86.4	2.1
1,4-Dichlorobenzene	86.5	88.4	85.3	86.7	1.6
1,2-Dichlorobenzene	88.8	82.6	84.7	85.4	3.2
Acrolein	24.6	19.9	21.7	22.1	2.4
Acrylonitrile	9.2	7.0	7.6	7.9	1.1
Pentane	86.1	78.8	83.2	82.7	3.7
Dimethyl Sulphide	79.3	78.9	82.4	80.2	1.9
Methylethylketone	8.5	10.9	6.9	8.8	2.0
Hexane	85.9	81.8	85.2	84.3	2.2
Heptane	99.6	95.9	97.8	97.8	1.9
4-Methyl-2-pentanone	25.4	27.8	26.6	26.6	1.2

TABLE I (cont'd)

RETENTION TIME REPRODUCIBILITY

	Run #1 RRT	Run #2 RRT	Run #3 RRT	Ave. RRT	+ Limits For RRT
Dichlorodifluoromethane	0.488	0.473	0.471	0.477	0.012
Chloromethane	0.496	0.482	0.480	0.486	0.012
Vinyl Chloride	0.506	0.491	0.487	0.495	0.012
Bromomethane	0.520	0.507	0.505	0.511	0.010
Chloroethane	0.524	0.513	0.511	0.516	0.010
Trichlorofluoromethane	0.549	0.544	0.542	0.545	0.005
1,1-Dichloroethylene	0.571	0.568	0.565	0.568	0.005
Dichloromethane	0.575	0.570	0.569	0.571	0.005
t-1,2-Dichloroethylene	0.609	0.608	0.607	0.608	0.002
1,1-Dichloroethane	0.614	0.614	0.613	0.614	0.002
Chloroform	0.660	0.662	0.660	0.661	0.002
1,2-Dichloroethane	0.694	0.682	0.693	0.690	0.009
1,1,1-Trichloroethane	0.708	0.710	0.704	0.707	0.004
Benzene	0.731	0.733	0.723	0.729	0.008
Carbon Tetrachloride	0.739	0.741	0.731	0.737	0.005
1,2-Dichloropropane	0.773	0.774	0.760	0.769	0.010
Bromodichloromethane	0.783	0.784	0.770	0.779	0.010
Trichloroethylene	0.786	0.787	0.772	0.782	0.010
1,3-Dichloropropene(Z)	0.832	0.833	0.817	0.827	0.010
1,3-Dichloropropene(E)	0.862	0.863	0.846	0.857	0.012
1,1,2-Trichloroethane	0.873	0.873	0.851	0.866	0.012
Toluene	0.892	0.892	0.881	0.888	0.005
Dibromochloromethane	0.915	0.916	0.910	0.914	0.005
Tetrachloroethylene	0.960	0.960	0.959	0.960	0.002
Chlorobenzene	1.003	1.003	1.002	1.003	0.002
Ethyl Benzene	1.027	1.026	1.026	1.026	0.002
m,p-Xylenes	1.038	1.038	1.037	1.038	0.002
Bromoform	1.042	1.042	1.041	1.042	0.002
o-Xylene	1.066	1.068	1.068	1.067	0.002
1,1,2,2-Tetrachloroethane	1.066	1.066	1.066	1.066	0.001
1,3-Dichlorobenzene	1.201	1.200	1.197	1.199	0.003
1,4-Dichlorobenzene	1.206	1.205	1.202	1.204	0.003
1,2-Dichlorobenzene	1.232	1.232	1.229	1.231	0.003
Acrolein	0.534	0.525	0.524	0.528	0.007
Acrylonitrile	0.555	0.550	0.548	0.551	0.005
Pentane	0.507	0.519	0.511	0.512	0.008
Dimethyl Sulphide	0.512	0.526	0.517	0.518	0.009
Methylethylketone	0.585	0.597	0.592	0.591	0.007
Hexane	0.617	0.626	0.623	0.622	0.006
Heptane	0.784	0.790	0.787	0.787	0.004
4-Methyl-2-pentanone	0.821	0.826	0.823	0.823	0.004

EXTRACTABLE (EPA) ANALYSIS - WATER SAMPLES

Standard Compound Characterization

A Standard solution containing approximately 1.0 ng/ul of each of the selected priority pollutants was prepared and analysed by GC/MS to determine each compound's fragmentation pattern, relative retention time (RRT) and relative response factor (RRF) compared to the internal standard D_{10} Phenanthrene. A 10 ppb dilution of this standard was routinely run prior to sample analysis to insure optimum performance of the GC/MS system. The minimum detection limit (MDL) represents the minimum level at which a compound can be detected and quantitated. Values were determined by comparison of the response of the labelled internal standards to the level of background interference in the region of the corresponding natural compound. These values are averages obtained from actual sample matrices.

Target Compound % Recovery

The % recovery of individual target compounds was determined by spiking 1 litre of purified distilled water at the 20 ppb level with a standard mixture containing all of the compounds of interest.

Recovery values and the method detection limit (MDL) are listed in Table II.

Sample Extractions

To monitor the extraction efficiency of individual sample extractions. Each sample was spiked at the 10 ppb level with a mixture of 11 deuterated acid extractables and 19 deuterated B/N compounds.

To monitor the injection efficiency all extracts were spiked with 10 ppb of D-10 Phenanthrene immediately prior to GC/MS analysis.

QA/QC Protocol

a) The use of a stock mixture of deuterated internal standards (Table III) to monitor extraction efficiency assures a high confidence level in the results of all sample extractions.

b) Travelling blanks were analysed at 10 sample intervals to insure that outside contamination was not interfering with the observed results.

c) Prior to sample analysis, reference standards at the 10 ppb level were analysed to demonstrate that the instrument was capable of the required sensitivity. Solvent blanks were run between standards and samples to monitor any possible cross contamination. Reference standards at various levels were analysed after every tenth sample.

Target Compound Identification and Quantitation

The GC/MS data files were searched for the selected pollutants using a computer program that searched successive regions of the chromatogram plotting out ion intensities of the two most abundant ions of both the target compound and labelled standards eluting in that region. The identity of detected compounds was verified by manual confirmation (mass spectra matching).

Quantitation of target compounds was achieved by comparing the peak heights of the natural compound to that of its analogous labelled standard which had been spiked into the sample at a known level. For those target compounds whose corresponding labelled standard was not available, the labelled standard that eluted closest to it was used for quantitation.

Additional Compound Identification

Additional compounds (non-targetted) present in the sample were tentatively identified by means of a computer generated mass spectra library search program. The mass spectra of the natural compound is compared to entries in the National Bureau of Standards (NBS) library containing approximately 35,000 compounds. The compounds reported as additional compounds were present in concentrations greater than 1 ppb (based on a 1:1 response to the internal standard, D_{10}-Phenanthrene) and had purity match values of greater than 800 (1000 = exact match).

TABLE II

EPA PRIORITY POLLUTANTS

MINIMUM DETECTION LIMITS & PERCENT RECOVERIES

(1 L water/20 ppb)

ACIDIC COMPOUNDS	MWT	QUANT ION	RRT	MDL	% REC
Phenol	94	94	0.270	1.6	25.0
2-Chlorophenol	142	142	0.390	3.0	40.6
2,4-Dimethyl phenol	136	107	0.431	2.5	24.5
p-Chloro-m-cresol	156	156	0.485	2.0	83.4
2,4-Dichlorophenol	176	176	0.559	2.9	47.9
2,4,6-Trichlorophenol	210	195	0.609	3.3	70.3
2-Nitrophenol	153	153	0.609	2.0	29.6
2,4-Dinitrophenol	198	91	0.772	5.0	16.5
4,6-Dinitro-o-cresol	212	265	0.921	4.0	77.5
Pentachlorophenol	280	280	0.962	3.5	80.9
4-Nitrophenol	153	153	0.652	2.1	27.0
2,4-D	234	199	0.877	2.5	94.2
Silvex	280	196	0.987	2.4	93.7

TABLE II (cont'd)

EPA PRIORITY POLLUTANTS
MINIMUM DETECTION LIMITS & PERCENT RECOVERIES
(1 L water/20 ppb)

Base/Neutral Compounds	MWT	QUANT ION	RRT	MDL	% REC
1,4-Dichlorobenzene	146	146	0.288	0.4	71.6
1,3-Dichlorobenzene	146	146	0.284	0.4	45.3
bis(2-Chloroisopropyl)ether	170	45	0.326	1.0	25.1
1,2-Dichlorobenzene	146	146	0.309	0.4	58.7
Nitrobenzene	123	77	0.348	0.5	30.3
N-Nitrosodi-n-propylamine	130	70	0.339	0.5	29.5
Hexachloroethane	234	117	0.354	2.0	83.2
Isophorone	138	82	0.389	0.4	98.2
bis(2-Chloroethoxy)methane	172	93	0.424	0.9	18.6
Naphthalene	128	128	0.460	0.4	55.9
1,2,4-Trichlorobenzene	180	182	0.454	1.3	61.7
Hexachlorobutadiene	258	225	0.506	0.5	61.6
Hexachlorocyclopentadiene	270	237	0.619	3.0	46.3
2-Chloronaphthalene	162	162	0.649	0.8	57.4
2,6-Dinitrotoluene	182	165	0.701	2.0	95.5
Dimethyl phthalate	194	163	0.712	1.0	100.0
Acenaphthylene	152	152	0.717	0.5	96.7
Acenaphthene	154	154	0.751	0.4	83.4
2,4-Dinitrotoluene	182	165	0.773	1.5	79.4
Diethyl phthalate	222	149	0.775	5.0	85.6
9H Fluorene	166	166	0.900	0.4	79.5
4-Chlorophenyl phenyl ether	204	204	0.849	1.0	97.5

TABLE II (cont'd)

BASE/NEUTRAL COMPOUNDS	MWT	QUANT ION	RRT	MDL	% REC
N-Nitrosodiphenylamine	198	169	0.868	0.4	67.0
1,2-Diphenyl hydrazine	184	77	0.877	0.6	75.9
4-Bromophenyl phenyl ether	248	248	0.937	0.5	70.7
Hexachlorobenzene	284	284	0.957	1.2	98.0
Phenanthrene	178	178	1.004	0.3	82.1
Anthracene	178	178	1.013	0.3	84.1
Di-n-butyl phthalate	278	149	1.138	0.4	76.3
Fluoranthene	202	202	1.193	0.6	88.5
Benzidene	184	184	1.211	10.0	68.0
Pyrene	202	202	1.250	0.5	88.8
Butylbenzyl phthalate	312	149	1.395	0.8	92.3
Chrysene	228	228	1.472	0.4	57.5
Benzo(a)anthracene	228	228	1.474	0.5	81.6
3,3-Dichlorobenzidene	252	252	1.470	0.7	69.6
Bis(2-ethylhexyl)phthalate	418	149	1.519	0.9	82.3
Di-n-octyl phthalate	386	149	1.637	1.5	95.3
Benzo(a)pyrene	252	252	1.657	0.3	69.7
Benzo(k)fluoranthene	252	252	1.661	0.4	63.1
Benzo(b)fluoranthene	252	252	1.712	0.6	53.4
Dibenzo(a,h)anthracene	278	278	1.967	4.0	50.2
Benzo(g,h,i)perylene	276	276	1.959	1.5	61.7
Indeno(1,2,3-CD)pyrene	276	276	1.966	1.3	71.2

TABLE II (cont'd)

ADDITIONAL COMPOUNDS

BASE/NEUTRAL COMPOUNDS	MWT	CHAR ION	RRT	MDL	% REC
4-Methyl Pyridine	93	93,92,66	.165	1.4	42.3
Benzothophene	134	134,90	.464	0.4	52.0
Benzothiazole	135	135,90	.489	0.4	33.7
Isoquinoline	129	129,102	.525	1.7	9.7
Napthalene,1-Methyl	142	142,141	.588	0.8	27.4
Napthalene,1,2-Dimethyl	156	156,141	.695	2.0	64.1
Dibenzofuran	168	168,139	.782	0.8	43.7
Napthalene-1,6,7-Trimethyl	170	170,155	.831	0.8	83.4
Diethyl Phthalate	222	149,177	.841	5.0	83.5
2-Methyl Anthracene	192	192,189	1.107	1.2	55.0
Benzo(b)fluoranthene	252	252,136	1.761	0.6	56.8
Benzo(a)pyrene	252	252,136	1.822	0.4	60.6

TABLE III

ISOTOPICALLY LABELLED INTERNAL STANDARDS

Compound	Natural Quant Ion	Deuterated Quant Ion
Acid Extractable		
4-Chloro-3-methylphenol,2.6-d_2	142	144
2-Chlorophenol-3,4,5,6-d_4	128	132
2,4-Dichlorophenol-3,5,6-d_3	162	164
2,4-Dimethylphenol-3,5,6-d_3	122	125
4,6-Dinitro-2-methylphenol-3,5-d_2	198	200
2,4-Dinitrophenol-3,5,6-d_3	184	187
2-Nitrophenol-3,4,5,6-d_4	139	143
4-Nitrophenol-2,3,5,6-d_4	139	143
Pentachlorophenol-$^{13}C_6$	266	272
Phenol-2,3,4,5,6-d_5	94	99
2,4,6-Trichlorophenol-3,5-d_2	196	198
Base/Neutrals		
Benz(a)anthracene-d_{12}	228	240
Benzyl n-Butyl Phthalate-3,4,5,6-d_4	149	153
Bis(2-chloroethoxy)-d_8-methane	93	101
Bis(2-ethylhexyl)Phthalate-3,4,5,6-d_4	149	153
Dibenzo(a,h)anthracene-d_{14}	278	292
1,2-Dichlorobenzene-d_4	146	153
1,4-Dichlorobenzene-d_4	146	153
Dimethyl Phthalate-3,4,5,6-d_4	163	167
2,6-Dinitrotoluene-a,a,a-d_3	165	168
Nitrobenzene-d_5	123	128
1,2,3-Trichlorobenzene-4,5,6-d_3	180	183
Acenaphthene-d_{10}	154	164
Anthracene-d_{10}	178	188
Benzo(k)fluoranthene-d_{12}	252	264
Bis(2-chloroethyl)-d_8 Ether	93	101
Chrysene-d_{12}	228	240
Fluorene-d_{10}	166	176
Naphthalene-d_8	128	136
Pyrene-d_{10}	202	212

EPA PRIORITY POLLUTANTS
EXTRACTABLE FRACTION - ANALYTICAL METHODOLOGY

EXTRACTION PROCEDURE

1) A 1 litre volume of sample water was spiked at the 10 ppb level with a mixture of deuterated standards (the sample was shaken and allowed to equilibrate for 1 hr at room temperature.

2) The pH was adjusted to a pH=11 using 6N NaOH and the sample extracted with three 50 ml volumes of CH_2Cl_2.

3) The aqueous portion was then acidified to pH=2 using 6N HCl and extracted with 3 x 50 ml volumes of CH_2Cl_2 to extract the acidic and phenolic compounds.

4) Similar organic extracts were combined and dried through a column of solvent washed Na_2SO_4 (acidified Na_2SO_4 for acid fraction).

5) The dried extracts were collected in 1 litre Kuderna-Danish evaporators containing 2 mls of isooctane then concentrated to a volume of approximately 10 ml.

6) The extracts were transferred to 15 ml graduated centrifuge tubes (a 2 x 1 ml isooctane rinse) then concentrated to a 10 ml volume using a gentle stream of N_2 and spiked with 10 ppb D_{10} Phenanthrene.

Gas Chromatographic/Mass Spectrometry Instrumentation

One ul aliquots of the 10 ml extracts were analysed for the presence of the selected priority pollutants using a Finnigan 4500 GC/MS system set to the following condition:

All injections were performed using an on column technique.

MASS SPECTROMETER

Electron Multiplier	-	1450 e.v.
Ionization Energy	-	70 e.v.
Sensitivity	-	10^8 amps/volt
Scan Rate	-	2.25 mSec/mass unit
Scan Range	-	1-2000
Mass Range	-	60-450 a.m.u.

Varian Gas Chromatograph Conditions

Instrument	-	Varian 3500
GC Column	-	DB-5 30 M capillary
GC Temp Program		
Initial	-	50°C (0.1 min)
Final	-	2850C (20 min)
Rate	-	10°C/min
Injection Port Temp	-	250°C
Column Carrier Gas	-	Helium

PESTICIDE ANALYSIS - WATER SAMPLES

The chlorinated pesticides were screened for via the EPA method 608. Analysis for the chlorinated compounds was conducted using a dual column electron capture detection GC system. Compound identification is based on the agreement of two separate retention times and of the relative ratio of the peak heights compared to those of a recently analysed pesticide standard.

Compound quantitation was performed by taking the ratio of the sample peak height to that of a recently analysed 10 ppt standard. Peak heights were measured manually using a valley to valley baseline. Corrections were made for background contamination and percent recovery.

Extraction Recovery

The percent recovery of individual compounds was determined by spiking pure water (solvent extracted reverse osmosis water) at both the 10 ppt and 50 ppt level with a standard mixture containing all of the compounds of interest. Averaged values from duplicate 10 ppt spikes (Table IV) were used for the final concentration corrections.

Extraction Background

Background contamination introduced by the extraction procedure was determined by the analysis of a solvent blank carried through the extraction procedure and clean up. Final concentrations were corrected by subtraction of these values.

ECD/GC Analysis

1 ul volumes were analysed on a Varian 6000 gas chromatograph equipped with two capillary columns leading from a single injector into two electron capture detectors. Injections were made using a Varian autosampler to insure reproducible aliquot volumes, hexane washes were run through the autosampler between each sample. Hexane blanks were injected prior to and during sample intervals to determine any background contamination introduced by the GC system. 10 pg pesticide standards were run routinely prior to the start of sample analysis followed by 5 sample intervals.

TABLE IV

PESTICIDE ANALYSIS - ECD/GC

Pesticide Compounds	% Recovery	MDL (ppb)
Hexachlorobenzene	98%	0.01
Alpha BHC	84%	0.01
Beta BHC	87%	0.01
Gamma BHC	70%	0.01
Delta BHC	88%	0.04
4,4°-DDD	85%	0.01
4,4°-DDE	75%	0.01
4,4°-DDT	90%	0.04
o,p°-DDD	83%	0.04
Methoxychlor	100%	0.50
Aldrin	73%	0.01
Heptachlor	80%	0.01
Dieldrin	17%	0.01
Heptachlor Epoxide	101%	0.01
Endrin	69%	0.01
Alpha Endosulfan	82%	0.01
Beta Endosulfan	100%	0.01
Oxychlordane	84%	0.01
Endosulfan Sulphate	95%	0.04
Mirex	87%	0.01
Endrin Aldehyde	100%	0.20
PCNB	100%	5.00
Photomirex	100%	0.01
Strobane	100%	5.00
Total PCB	94%	0.05
Nitrogen Phosphorus/GC		
Ametryne	98%	5.00
Atrazine	103%	5.00
Captan	100%	5.00
Diazinon	118%	5.00
Dichloran	100%	1.00
Malathion	101%	5.00
Methyl Parathion	98%	5.00
Ethyl Parathion	101%	5.00

TABLE IV (Cont'd.)

POLYCHLORINATED BIPHENYLS

PCB	QUANT ION	% RECOVERY	MDL (ppt)
1016	114 260 294	87	50
1232	486 190 260	89	50
1248	294 326 362	94	50
1260	326 360 394	72	50
1242	224 260 294	86	50
1221	190 224 260	83	50
1254	294 326	79	50
Chlordane	373 375 377	58	200
Toxaphene	159 231 231	71	200

Chlorinated Pesticides

Extraction Procedure

All glassware was detergent washed, rinsed successively with distilled water, glass distilled acetone and glass distilled dichloromethane prior to use.

- 1 liter volumes of sample water were extracted using 3 x 70 ml volumes of CH_2Cl_2 (initial volume used to rinse sample container)
- the combined extract was dried through a solvent prewashed column of Na_2SO_4, 20 ml hexane and 5 ml of isooctane were added. The extract was then concentrated to approximately 2 ml using a Kuderna-Danish evaporator.

Florisil Clean-Up

- Florisil purified by soxhlet extraction with CH_2Cl_2 and activated at 130°C
- the sample extract was applied to a hexane washed column consisting of a 15 cm x 1 cm column of florisil

The pesticides were eluted in the following fractions:

1st fraction - 70 ml 5% ether/hexane
2nd fraction - 70 ml 20% ether/hexane

1 ml of isooctane was added to the extract and concentrated by rotary evaporation (room temp.) to 5 ml then concentrated to 1 ml using a gentle stream of N_2.

1 ul volumes of extract were analysed using a capillary column gas chromatograph equipped with an electron capture detector.

Gas Chromatographic Conditions - Pesticide Analysis

Electron Capture
GC - Varian Vista 6000
Column - DB-5 0.25 mm I.D. 30 M and
DB-17 0.25 mm I.D. x 30 M
Carrier gas - N_2
Flow - 3 ml/min
Detector - 63 Ni ECD x 2

Temp. Program

	Final Temp.	Rate (c/min)	Hold Time
Initial temp = 140°C (2 min.)	180	6.0	0.0
	210	2.0	0.0
	250	4.0	2.0

DIOXIN WATER ANALYSIS METHODOLOGY

EXTRACTION PROCEDURE

- a measured volume of water sample (typically 1 litre) was spiked at a level of 10 ppt with a mixture containing isotopically labelled C13-2,3,7,8-TCDD and C13-OCDD
- the sample was then extracted with 4 x 30 ml Ch_2Cl_2
- the extract was dried (Na_2SO_4) and concentrated to near dryness, and re-dissolved in hexane
- the extract was subjected to a multi adsorbent column clean up (U.S. EPA method, option B) to reduce sample background

GC/MS ANALYSIS

Analysis was conducted using a Varian 3500 GC coupled to a Finnigan 4000/4500 MS system in the electron impact, MID mode. Prior to analysis the instrument was turned to optimum performance in 300-500 mass range.

GC/MS Conditions

Electron energy	=	33 ev
Electron multiplier	=	1650 ev
Electrometer range	=	10-8

GC Parameters

Column DB-5 0.32 mm I.D., 30 M supplied by J & W	
Carrier Gas	He, 3 ml/min
Temp Program	80°C (1 min) to 180°C by 20°C/min to 275°C by 10°C/min to 285°C by 20°C/min Final hold time of 15 minutes
Injector Temp	100°C to 275°C by 100°C/min Final hold time of 1 minute

All injections were conducted using an on column injection technique.

ANALYSIS AND COMPOUND IDENTIFICATION

Analysis was conducted by MID GC/MS operating under E.I. conditions optimized for the m/e range 300-500.

MID descriptors were developed to scan for 3 or 4 ions in the parent cluster of each congener group. Confirmation of identity was achieved by full scan analysis or the MID monitoring of daughter ion clusters (M+-COCI).

Retention time elution regions and parent ion cluster ratios were determined using reference standards prior to sample analysis. MID descriptors were changed by a computer program. Solvent blanks were routinely run between standards and samples to determine the presence of instrument contamination.

Compound identification was based on the agreement of both elution retention times and parent ion cluster ratios between the sample and standard solutions containing at least one representative isomer from each of the PCDD/PCDF congener groups.

Quantitation was achieved on the basis of the area response of the labelled internal standards added to the sample at the 1 ppb and 5 ppb levels for TCDD and OCDD respectively.

Minimum detection limits (MDL)are defined as:

$$MDL = \frac{3 \times \text{Ht of natural background}}{\text{Ht of 1 ppb labelled internal standard}}$$

REFERENCE STANDARDS

PCDD/PCDF CONGENERS PRESENT IN REFERENCE STANDARD

Dioxins			Furans		
2,3,7.8	-	TCDD	2,3,7,8	-	TCDF
1,2,7,8	-	TCDD	2,3,4,8	-	TCDF
1,2,3,7,8	-	P_5CDD	1,2,4,8	-	TCDF
1,2,3,4,7,8	-	H_6CDD	1,2,3,7,8	-	P_5CDF
1,2,3,4,6,7,8	-	H_7CDD	2,3,4,7,8	-	P_5CDF
OCDD			2,3,4,6,7,8	-	H_6CDF
			OCDF		

Mixtures of the above were supplied by Dr. R. Lao - E.P.S., River Road Laboratories, Ottawa (conc. 100 pg/ul)

Individual Standards - Caledon Laboratories

2,3,7,8-TCDD	Lot# 6-182	purity = 95-98%
1,2,3,4-TCDD	Lot# 7860G	purity = 95-98%
OCDD	Lot# 6690G	purity = 95-98%
OCDF	Lot# 3650G	purity = 95-98%

Isotopically Labelled Internal Standards - KOR Isotopes

2,3,7,8-TCDD (^{13C}-12) Lot# J-2-70 purity = 98+%, Conc = 50 ug/ml

OCDD (^{13C}-12) Lot# SSY-8-78 purity = 99%, Conc = 50 ug/ml

Standard Reference Material #1614

A standard reference solution of 2,3,7,8-TCDD supplied by the National Bureau of Standards is used to insure the accuracy of the C_{13}-2,3,7,8-TCDD internal standard.

APPENDIX B.5

QUALITY ASSURANCE/QUALITY CONTROL PROTOCOLS
STANDARD BIOLOGICAL LABORATORIES

Bioceutical Research **Standard Biological Laboratories**

Divisions of SGS Supervision Services Inc.

GROWTH PROMOTION - PROCEDURE

The growth promoting qualities of each selective medium is evaluated by running it in parallel with a non-selective medium using specific control organisms. Stock cultures of these organisms are incubated for 24 hours at 35°C ± 1°C in Tryptone Soya Broth, then serially diluted in sterile phosphate buffer dilution blanks to achieve a bacterial density of approximately 10-200 colonies per ml of inoculum. Since it is possible that more than one dilution will have a bacterial concentration falling within this range, each medium (selective and non-selective) is inoculated by passing 1 ml of the selected dilutions through a membrane filter which is then placed onto the surface of the agar medium. To provide a comparison of recovery rates on membrane filters versus those obtained through the standard pour plate technique, the dilutions employed are, in addition, directly plated with the non-selective medium. The analysis on each selected dilution is performed in triplicate from which a mean value for the recovery is obtained.

514-516 Lakeshore Road East Mississauga, Ontario L5G 1J3 Telephone: (416) 274-2531

Bioceutical Research **Standard Biological Laboratories**

Divisions of SGS Supervision Services Inc.

RECOVERY PROCEDURE FOR FECAL STREPTOCOCCI

MEDIUM:	m - Enterococcus Agar
FORMULATION:	Available in dehydrated form
PREPARATION:	According to manufacturers directions
TECHNIQUE:	Membrane filtration using Gelman GN-6 filters, 47 mm diameter, 0.45 um pore size
INCUBATION:	35°C ± 1°C
TIME:	48 hours ± 2 hours
READING:	Use a binocular stereomicroscope set at 8X magnification. Target colonies are pink to dark maroon.

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DEHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Manufacturer	Lot No.:	Expiry Date
m-Enterococcus Agar	Difco	598336	3/88

Storage

Store at room temperature in tightly sealed containers.

Sterilization

The medium is not autoclaved
Heat with frequent agitation to dissolve agar and dispense into sterile petri dishes

Product Information

The dehydrated medium is a light beige, homogenous, free-flowing powder.
It is a superior selective medium for the detection of fecal streptococci at 35°C - 37°C.
The medium is 100% selective for fecal streptococci.

Comments

Autoclaving or overheating of the medium will adversely affect the quality and performance.

Bioceutical Research **Standard Biological Laboratories**

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Enterococcus Agar	01	200mls	February 7/86

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
light amber	Solid, clear, firm gel	acceptable

Precipitates	pH	Comments
none	7.25	no lumps or excessive moisture

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hrs.	No growth	
35°C	72 hrs.	No growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
S. faecalis (+ve control	35°C	48 hrs.	- pink to dark maroon colonies - typical morphology
E. coli (-ve control)	35°C	48 hrs.	- no growth
S. aureus (-ve control)	35°C	48 hrs.	- no growth

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Fecal Streptococci
Selective Medium: m-Enterococcus Agar Batch I.D. No.: 01
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Streptococcus faecalis
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Enterococcus Agar (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	167	25	178	24	169	23
	178	20	166	25	175	19
	180	20	174	21	176	22
Mean	175	21.7	172.7	23.3	173.3	21.3

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Enterococcus Agar	02	200 mls	March 6/86

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
light amber	Solid, clear, firm gel	acceptable

Precipitates	pH	Comments
none	7.20	no lumps or excessive moisture

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hrs.	no growth	
35°C	72 hrs.	no growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
S. faecalis (+ve control	35°C	48 hrs.	- pink to dark maroon colonies - typical morphology
E. coli (-ve control)	35°C	48 hrs.	- no growth
S. aureus (-ve control)	35°C	48 hrs.	- no growth

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Fecal Streptococci
Selective Medium: m-Enterococcus Agar Batch I.D. No.: 02
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Streptococcus faecalis
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Enterococcus Agar (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	185	20	185	19	182	19
	188	25	195	28	191	22
	189	24	191	23	186	26
Mean	187.3	23	190.3	23.3	186.3	22.3

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Enterococcus Agar	03	200 mls	March 31/86

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
light amber	Solid, clear, firm gel	acceptable

Precipitates	pH	Comments
none	7.20	no lumps or excessive moisture

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hrs.	no growth	
35°C	72 hrs.	no growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
S. faecalis (+ve control	35°C	48 hrs.	- pink to dark maroon colonies - typical morphology
E. coli (-ve control)	35°C	48 hrs.	- no growth
S. auerus (-ve control)	35°C	48 hrs.	- no growth

Bioceutical Research **Standard Biological Laboratories**

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Fecal Streptococci
Selective Medium: m-Enterococcus Agar Batch I.D. No.: 03
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Streptococcus faecalis
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Enterococcus Agar (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	254	29	265	28	258	37
	267	31	260	33	250	31
	264	33	253	33	264	32
Mean	261.7	31	259.3	31.3	257.3	33.3

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RECOVERY PROCEDURE FOR TOTAL COLIFORMS

MEDIUM:	m - Endo Agar LES
FORMULATION:	Available in dehydrated form
PREPARATION:	According to manufacturers directions
TECHNIQUE:	Membrane filtration using Gelman GN-6 filters, 47mm diameter, 0.45 um pore size.
INCUBATION:	35°C ± 1°C
TIME:	24 hours ± 1 hour
READING:	Target colonies are red and have a green metallic sheen. Background colonies are generally all other types. (i.e. red, colourless)

Bioceutical Research **Standard Biological Laboratories**

Divisions of SGS Supervision Services Inc.

DEHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Manufacturer	Lot No.:	Expiry Date
m-Endo Agar Les	Difco	612709	2/87

Storage

Store at room temperature in tightly sealed containers

Sterilization

The medium is not autoclaved.

Heat with frequent agitation to dissolve agar and dispense into sterile petri dishes.

Product Information

The dehydrated medium is a purple, homogenous free-flowing powder.

It is a selective medium for the enumeration of coliform organisms in water by membrane filtration.

Comments

Autoclaving or overheating of the medium will adversely effect the quality and performance.

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Endo Agar LES	01	200mls	February 7, 1986

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
Rose	Solid, firm, clear gel	acceptable

Precipitates	pH	Comments
none	7.20	-prepared plates should be protected from light -storage up to 2 weeks at 2-8°C

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hours	No growth	
35°C	72 hours	No growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
Escherichia coli (+ control)	35°C	24 hours	-colonies with gree metallic sheen
Salmonella typhimurium (-ve control)	35°C	24 hours	-red colonies without metallic sheen
Staphylococcus aureus (-ve control)	35°C	24 hours	-no growth

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Bioceutical Research **Standard Biological Laboratories**

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Total Coliforms
Selective Medium: m-Endo Agar LES Batch I.D. No.: 01
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Escherichia coli
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Endo Agar LES (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	190	23	176	20	186	21
	182	19	182	18	175	17
	183	20	187	17	183	19
Mean	185	20.7	181.7	18.3	181.3	19

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Endo Agar LES	02	200mls	March 6, 1986

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
Rose	Solid, firm, clear gel	acceptable

Precipitates	pH	Comments
none	7.15	-prepared plates should be protected from light -storage up to 2 weeks at 2-8°C

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hours	No growth	
35°C	72 hours	No growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
Escherichia coli (+ control)	35°C	24 hours	-colonies with green metallic sheen
Salmonella typhimurium (-ve control)	35°C	24 hours	-red colonies without metallic sheen
Staphylococcus aureus (-ve control)	35°C	24 hours	-no growth

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Total Coliforms
Selective Medium: m-Endo Agar LES Batch I.D. No.: 02
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Escherichia coli
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Endo Agar LES (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	130	12	120	15	126	14
	124	14	126	11	127	13
	122	12	117	17	118	10
Mean	125.3	12.7	121	14.3	123.7	12.3

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Endo Agar LES	03	200mls	March 31, 1986

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
Rose	Solid, firm, clear gel	acceptable

Precipitates	pH	Comments
none	7.20	-prepared plates should be protected from light -storage up to 2 weeks at 2-8°C

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hours	No growth	
35°C	72 hours	No growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
Escherichia coli (+ control)	35°C	24 hours	-colonies with green metallic sheen
Salmonella typhimurium (-ve control)	35°C	24 hours	-red colonies without metallic sheen
Staphylococcus aureus (-ve control)	35°C	24 hours	-no growth

GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Total Coliforms
Selective Medium: m-Endo Agar LES Batch I.D. No.: 03
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Escherichia coli
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Endo Agar LES (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	95	10	93	9	93	12
	100	13	96	10	94	10
	97	11	97	9	97	10
Mean	97.3	11.3	95.3	9.3	94.7	10.7

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RECOVERY PROCEDURE FOR FECAL COLIFORMS

MEDIUM: m - Tec Agar

FORMULATION:

	per litre distilled water
Proteose Peptone No. 3	5.0g
Yeast Extract	3.0g
Lactose	10.0g
Sodium Chloride	7.5g
Potassium Phosphate Dibasic	3.3g
Potassium Phosphate Monobasic	1.0g
Sodium Lauryl Sulphate	0.2g
Sodium Deoxycholate	0.1g
Bromocresol Purple	0.08g
Bromophenol Red	0.08g
Agar	15.0g

PREPARATION:
Mix ingredients into 1 litre of distilled water
Heat to 90°C to dissolve agar
Autoclave 15 minutes, 15 psi (121°C)
Cool to approximately 50°C and dispense into sterile petri dishes.
Final surface pH - 7.1 ± 0.1

TECHNIQUE:
Membrane filtration using Gelman GN-6 filter, 47mm diameter, 0.45 um pore size.

INCUBATION:
Incubate plates in a closed plastic container with two 50 ml ice packs and a moist sponge.

TEMPERATURE: 44.5°C ± 0.5°C

TIME: 23 ± 1 hour

READING:
Use a binocular stereomicroscope set at 8 X magnification
Target colonies are generally bright yellow, yellow, yellow brown, or yellow green.
Background colonies are generally, all other types (i.e. clear, blue or blue green)

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Tec Agar	01	500 mls	February 7, 1986

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
Deep Purple	Solid, firm, clear, gel	Acceptable

Precipitates	pH	Comments
None	7.10	

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hrs	No growth	
35°C	72 hrs	No growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
Escherichia coli (+ve control)	44.5°C	24 hrs	- yellow colonies typical morphology
Pseudomonas aeruginosa (-ve control)	44.5°C	24 hrs	- blue colonies typical morphology
Staphylococcus aureus (-ve control)	44.5°C	24 hrs	- no growth

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Fecal Coliforms
Selective Medium: m-Tec Agar Batch I.D. No.: 01
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Escherichia coli
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Tec Agar (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	95	10	91	11	90	8
	90	9	93	10	88	9
	89	8	87	8	87	8
mean	91.3	9	90.3	9.7	88.3	8.3

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Tec Agar	02	200 mls	March 6, 1986

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
Deep purple	Solid, firm, clear gel	Acceptable

Precipitates	pH	Comments
None	7.15	

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hrs	No growth	
35°C	72 hrs	No growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
Escherichia coli (+ve control)	44.5°C	24 hrs	- yellow colonies typical morphology
Pseudomonas aeruginosa (-ve control)	44.5°C	24 hrs	- blue colonies typical morphology
Staphylococcus aureus (-ve control)	44.5°C	24 hrs	- no growth

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Fecal Coliforms
Selective Medium: m-Tec Agar Batch I.D. No.: 02
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Escherichia coli
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Tec Agar (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	110	14	111	11	114	12
	106	13	117	13	108	10
	112	14	108	15	107	14
mean	109.3	13.7	112	13	109.7	12

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REHYDRATED MEDIA - QUALITY CONTROL RECORD

Medium	Batch I.D. No.	Amount Prepared	Date Prepared
m-Tec Agar	03	200 mls	March 31, 1986

PHYSICAL CHARACTERISTICS

Colour	Texture/Clarity	Thickness (of plated agar)
Deep purple	Solid, firm, clear, gel	Acceptable

Precipitates	pH	Comments
None	7.10	

STERILITY

Incubation Temp.	Incubation Time	Result	Comments
20°C	72 hrs	No growth	
35°C	72 hrs	No growth	

GROWTH PROMOTION - QUALITATIVE EVALUATION

Control Organism	Incubation Temp.	Incubation Time	Result
Escherichia coli (+ve control)	44.5°C	24 hrs	- yellow colonies - typical morphology
Pseudomonas aeruginosa (-ve control)	44.5°C	24 hrs	- blue colonies - typical morphology
Staphylococcus aureus (-ve control)	44.5°C	24 hrs	- No growth

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GROWTH PROMOTION - QUANTITATIVE EVALUATION

Parameter: Fecal Coliforms
Selective Medium: m-Tec Agar Batch I.D. No.: 03
Non-Selective Medium: Tryptone Soya Agar
Control Organism(+ve): Escherichia coli
Dilutions: 10^{-7}, 10^{-8}

Results:

Recovery (colony forming units)

	Tryptone Soya Agar (Membrane Filtration)		Tryptone Soya Agar (Direct Plating)		m-Tec Agar (Membrane Filtration)	
	10^{-7}	10^{-8}	10^{-7}	10^{-8}	10^{-7}	10^{-8}
	100	10	97	9	101	8
	96	13	104	10	96	10
	103	9	99	9	99	9
mean	99.7	10.7	100	9.3	98.7	9

RECOVERY PROCEDURE FOR BACKGROUND COUNT

MEDIUM: CPS Agar

FORMULATION:

	per litre distilled water
Soluble casein	0.5g
Peptone	0.5g
Soluble starch	0.5g
Glycerol	1.0g
Potassium Phosphate Dibasic	0.2g
Magnesium Sulphate Septahydrate	0.05g
Ferric Chloride (0.5% aq sol'n)	0.2ml
Agar	20.0g

PREPARATION:

Mix ingredients into 1 litre of distilled water
Heat to 90°C to dissolve agar
Autoclave 18 minutes, 15 psi (121°C)
Cool to approximately 50°C
Aseptically add 100 ppm actidone (cycloheximide)
Pour media into sterile petri dishes and allow to dry under laminar flow.

TECHNIQUE:

Spot Plate
Inoculate plates with 0.1 mls of sample appropriately diluted to give between 30 and 75 colonies.

INCUBATION:

Incubate plates in a closed plastic container containing a moist sponge.

TEMPERATURE: 20°C ± 1°C

TIME: 7 days

READING:

Count all colonies using a binocular stereomicroscope set at 8 X magnification.

APPENDIX B.6

QUALITY ASSURANCE/QUALITY CONTROL PROTOCOLS
ONTARIO RESEARCH FOUNDTION

Report No. 48-40464

Analyses and Quality Assurance Data for Sample 9925-0581 to 0583, - 0592 to 0600

to

M.M. Dillon Ltd.
47 Sheppard Avenue East
Willowdale, Ontario

Attention: Mr. J. McEwen

by

J.A. Lindsay
D.K. Smith
N.S. Belson
A.R. Kean
M.A. Brown

Environmental and Chemical Engineering Division

May 21st, 1986

ONTARIO RESEARCH FOUNDATION

SHERIDAN PARK RESEARCH COMMUNITY

MISSISSAUGA, ONTARIO, CANADA L5K 1B3 • (416) 822 4111 • TELEX 06-982311

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The following is drawn mainly from the QA/QC report number 48-40464. The analyses and quality assurance data has been removed as it does not pertain to this report. This section has been supplemented by report BCE 86-002 which was previously provided to M.M. Dillon Limited by ORF.

GENERAL CHEMISTRY (including BOD, Phenolics, Cyanide, Sulfide and Nutrients but excluding major cations)

The parameters to be analyzed will consist of those listed in the request for quotation by M.M. Dillon Limited, January 16, 1986.

SAMPLING

The sample containers and volumes of sample required, cleaning procedures, sampling procedures, preservation and shipping procedure for each set of samples will be agreed upon between ORF and the client.

ANALYTICAL

It should be noted that general chemistry parameters such as pH and dissolved oxygen should be done on site.

METHODS

The methods of analysis proposed are those contained in "Standard Methods for the Examination of Water and Wastewater" 16th Edition, 1985 (APHA, AWWA, WPCF).

LIMITS OF DETECTION

The limits of detection meet or exceed those requested with the exception of those for cyanide (ORF 2 µg/L; requested 1 µg/L) and total sulfide (ORF 20 µg/L; requested 1 µg/L).

QA/QC

A minimum of 10% duplicates, 10% internal blanks, 10% spiked samples and 10 % standards are routinely run with batches of samples. For single sample submissions duplicates, a spiked sample, standard(s) and internal blanks would be run. This would apply to all parameters requested with the following exceptions.

BOD_5 - duplicates and standard

pH, conductivity, turbidity, total dissolved solids, dissolved oxygen, alkalinity - duplicate determinations and standardization only.

N.B.

A field or travelling blank or other external reference or spiked samples submitted by the client as part of QA/QC with samples will count as separate sample(s) for cost purposes.

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PART B
GENERAL CHEMISTRY
(Including Nutrients and Anions)

SECTION I: ANALYTICAL PROCEDURES

pH - SM* No. 423

The pH was measured at 25°C on duplicate aliquots of sample within two hours of receipt. The pH meter (Orion Model 601A) and electrode (Ross Orion Model 81-55 combination) underwent a three point (pH 4, 7, and 10) calibration check using fresh buffer solutions before and after sample pH measurements.

Alkalinity - SM No. 403

Alkalinity was done on the aliquots immediately after pH measurement. The sample was titrated to pH 4.5 with acid, (standardized against sodium carbonate).

Conductivity - SM No. 205

Conductivity was measured at 25°C using a Wheatstone Bridge (YSI Model 31) and a platinized conductivity cell. The cell constant (1.00) was checked using 0.001 N and 0.01 N KCl solutions.

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* Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF, 16th Edition, 1985.

Turbidity - SM No. 214A

Turbidity was measured at 2o to 25°C after appropriate dilution, using an HF Instrument Model DRT-200 Turbidimeter. The turbidimeter was standardized using a formazin polymer standard suspension at 40 NTU.

Total Dissolved Solids - SM No. 95

Procelain crucibles were fired at 600°C, placed in a desiccator until cool, and weighed on a Mettler Model AE160 analytical balance. An aliquot of sample, filtered through a pre-fired glass fibre filter (Whatman Grade 934-AH, 1.5 µm retention), was placed in a pre-fired crucible and dried at 103°C in a convection oven to constant weight.

Anions by Ion Chromatography - SM No. 429

Fluoride, chloride, bromide, nitrate and sulphate were determined within 24 hours of receipt, by direct injection of a filtered aliquot of sample into the anion system of a Model 16 Dionex Ion Chromatography equipped with a conductivity detector.

Columns used were a "normal" gaurd column (Dionex P/N 030825), separator column (Dionex P/N 030827), and suppressor column (Dionex P/N 030828) using 0.003 M $NaHCO_3$/0.0024 M Na_2CO_3 as eluant. Quantification was by method of external standards.

Nitrite - SM No. 419

Nitrite was determined colorimetrically on aliquots of sample within 24 hours of receipt by reaction with sulphamic acid and NED dihydrochloride reagents.

Ortho-Phospahte - SM No. 424E

Phosphate was determined on aliquots of sulphuric acid preserved sample by the ammonium molybdate-stannous chloride colorimetric procedure.

Total Phosphorus - SM No. 424 C III and E

Aliquots of sample preserved with sulphuric acid were digested with sulphuric acid and potassium persulphate. After neutralization, the o-PO_4 content of the digestate was determined by the ammonium molybdate-stannous chloride colorimetric procedure.

Total Organic Carbon - non purgeable - SM No. 505A

Immediately upon receipt, aliquots of sample were acidified to pH 2 with phosphoric acid. After homogenizing the aliquots, inorganic carbon was removed by sparging with nitrogen. Non-purgeable total organic carbon was then determined by combustion-infrared using the total carbon channel of a Beckman Model 915A Carbon Analyser equipped with a Model 865 Infrared Analyser. Determinations were made on an average of at least five injections.

Ammonia-Nitrogen - SM No. 417 A & B

Aliquots of sulphuric acid preserved sample were distilled from borate buffered, pH 9.5 solution and ammonia trapped in boric acid absorbant. Ammonia in the absorbant was determined by nesslerization.

Total Kjeldahl Nitrogen - SM No. 420 B

Aliquots of sulphuric acid preserved sample were digested with sulphuric acid and potassium sulphate using selenium as a catalyst on a Technicon BD 40 Block Digester. The digestates were then micro-steam distilled from strongly alkaline sodium hydroxide/sodium thiosulphate solution and ammonia trapped in boric acid solution. Ammonia in the absorbant was determined by nesslerization.

Cyanide - SM No. 412 A, B & D

Cyanide was determined on aliquots of sodium hydroxide preserved sample within two hours of receipt by reflux digestion/distillation from strong acid solution using magnesium chloride as a catalyst. Liberated HCN was trapped in sodium hydroxide absorbant using vaccuum and quantified using the pyridine-barbituric acid colorimetric procedure.

Sulphide - SM No. 427 B & D

Aliquots of the sodium bicarbonate preserved sample were concentrated by the addition of zinc acetate solution at pH >9 in a BOD bottle. After filtration through a glass fibre disc, sulphide in the precipitate (retentate) was determined iodometrically.

Phenolic Compounds

Reference: Ontario Ministry of the Environment "Determination of Phenolic Compounds - Method A.

Phenolic compounds were determined within two hours of receipt using a Technicon automated distillation-colorimetric procedure. Aliquots of phosphoric acid preserved sample were distilled from phosphoric acid pH 4.0 solution, the steam distillate buffered with sodium tetraborate solution and phenolic compounds reacted wtih 4-aminophenozone and potassium ferricyanide solutions.

SECTION II - QUALITY ASSURANCE PROCEDURES

Method Blank

An aliquot of suitable water (i.e., deionized, ammonia free, organic free water as required by the analytical procedure) was processed and analysed exactly as the sample for the following parameters:

Conductivity, turbidity, nitrate, nitrite, sulphate, phosphate, total phosphorus, total organic carbon, ammonia, TKN, cyanide, sulphide, and phenolic compounds.

Field Blank

An aliquot of the sulphuric acid preserved field blank provided was analysed for ammonia, TKN, phosphate and total phosphorus.

Replicates

All analyses were performed in duplicate.

Standard Additions to Samples (Spikes)

Known amounts of standards (authenticated where possible) were added to aliquots of sample at a level approximating that of the amount found in the sample. These "spikes" were analysed in exactly the same manner as the sample. Standard additions to samples were done on the following analyses: fluoride, chloride, nitrate, sulphate, nitrite, phosphate, total phosphorus, ammonia, TKN, cyanide and phenolic compounds.

Standard Additions to Blank Water (Method Standard)

Where appropriate, amounts of standard were added to blank water prior to digestion, distillation or other pretreatment and recoveries determined against standards analysed directly. Method standard recoveries were performed on the following analyses: total phosphorus, ammonia, TKN and cyanide.

MAJOR CATIONS, TRACE METAL CONSTITUENTS (HEALTH), TRACE METAL CONSTITUENTS (AESTHETIC)

SAMPLING

Sample containers, volumes of sample required, cleaning procedures, sampling instructions, preservatives and shipping procedure for each set of samples will be agreed to between ORF and the client.

ANALYTICAL

Tables I ano II outline the trace metal parameter of interest and detection limits attainable using a variety of analytical procedures. The most costly combination has been used in the summary total cost estimation sheet since these more expensive procedures are expected to meet or exceed the minimum detection limit requested. the indicated prices are based upon one sample received per submission. Subsequent samples within a given submission may be analyzed for less. This is owing to the costs associated with sample digestion, instrument set up and the required quality control procedures. Substantial savings could be made if samples may be preserved upon collection and analyzed in groups at regular intervals.

QA/QC

Quality control procedures include reagent blanks, replicate analyses, and spiked samples processed and analyzed with each sample group.

TABLE 1

TRACE ELEMENTS (Health)

Parameter	Procedure	Detection[1] Limit (µg/L)
Lead, Cadmium	ASV[3]	0.2, 0.1
Lead, Cadmium	FAA[4]	20, 2
Chromium	FAA	10
Chromium	SX-AA[5]	0.5
Arsenic[6]	HGAA[7]	0.5
Mercury	CVAA8	0.1

1 Detection Limits - expected detection limits based upon "normal" water samples - absence of unusual interferences.

3 ASV - Anodic stripping voltammetry - hanging mercury drop - quantitation by method of standard addition

4 FAA - D_2 arc background corrected flame atomic absorption

5 SX-AA - APDC/MIBK solvent extraction - flame atomic absorption

6 Se, Te, Sb may be analyzed at an additional cost of $30/element/sample

7 HGAA - Hydride generation atomic absorption - $NaBH_4$ reduction

8 CVAA - Cold vapour atomic absorption

NOTE: Detailed procedures are available upon request.

TABLE 2

MAJOR CATIONS - includes metals under "Trace Constiutuents (Aesthetic)"

All elements will be analyzed by DC Plasma Emission Spectrophotometry. Flame atomic absorption will be used to confirm results for zinc and other metals, if necessary.

Element	Detection Limit (DCP)(µg/L)	
Iron	10	
Manganese	10	
Aluminum	10	
Copper	10	(FAA-5)
Zinc	30	(FAA-5)
Calcium	50	
Sodium	10	
Potassium	100	
Magnesium	10	
Silicon	10	
Boron	10	
Cobalt	10	
Bismuth	200	
Beryllium	2	
Vanadium	10	
Molybdenum	20	
Nickel	10	

PART C
TRACE METALS

PROCEDURE

Multielement

Aliquots of the sample (25 mL) were digested with dilute aqua regia. The resulting solutions were diluted to volume for analysis by DC plasma emission spectrophotometry. Zinc results were confirmed by flame atomic absorption spectrophotometry.

Cadmium and Lead

An aliquot (5 mL) of the solution was placed in a glass cell. High purity nitric acid (0.5 mL) and a purified acetate-tartrate buffer (4.5 mL) were added. The solution was analyzed for cadmium and lead by anodic stripping voltammetry. Quantitation was by method of standard additions.

Arsenic

Aliquots of the sample (25 mL) were digested with sulphuric and nitric acids to fumes of sulphur trioxide. The resulting solutions were diluted to volume with 20% hydrochloric acid for analysis by hydride generation atomic absorption spectrophotometry. Sodium borohydride was used as the reductant.

Mercury

Aliquots of the sample (50 mLs) wwere digested at 90°C with sulphuric and nitric acids, potassium persulphate and potassium permanganate. The resulting solutions were reduced with hydroxylamine hydrochloride and diluted to volume. The solutions were further reduced with stannous chloride immediately before analysis by cold vapour atomic absorption spectrophotometry.

QUALITY ASSURANCE AND QUALITY CONTROL

Reagent blanks, replicate and spiked samples were processed and analysed.

M. Adele Brown

M.A. Brown

Ross Kean

A.R. Kean

Metal Analytical
Environmental and Chemical Engineering Division

BACTERIOLOGICAL (excluding BOD_5)

ANALYTICAL

It is proposed to use the membrane filter techniques for each parameter as specified in "Standard Methods for the Examination of Water and Wastewater" 16th Ed., 1985. The cost per sample of $300 includes QA/QC.

QA/QC

The quality control would follow the procedures stated in Standard Methods for the Examination of Water and Wastewater (16th edition, 1985). Total coliform counts would be verified by a test for lactose fermentation whereby growth from sheen colonies is inoculated in parallel to tubes of lauryl tryptose broth and brilliant green lactose bile broth; both tubes would then be incubated at $35^{o}C \pm 0.5^{o}C$ for 48 hours. Gas formed within 48 hours verifies a colony as a coliform. If only the lauryl tryptose broth tube produces gas, a transfer to a second brilliant green lactose bile broth tube is required. Verification of a coliform requires gas be produced within 48 hours.

In addition to the verification test, a known density of coliforms will be filtered and incubated to show that the media employed does detect total coliform counts (positive control). A second control (negative) of organism(s) not in the coliform group will be filtered to ensure the media employed does not detect non-coliform organisms. These organisms will be used throughout the confirmation tests as controls as well.

Normally few nonfecal coliforms are detected on M-FC medium due to the selective action of elevated temperature and the rosolic acid salt reagent in the medium. Positive and negative controls of fecal coliforms will be run in conjunction with each set of samples to verify the ability of M-FC medium to detect fecal coliforms.

The confirmed test for fecal streptococcal organisms (the red and pink colonies growing on filters on KF agar) requires that typical colonies be inoculated onto brain-heart infusion agar slants. When growth is detected a loopful of the growth is transferred from the brain-heart infusion agar slant to a clean microscope slide and fresh 3% hydrogen peroxide added to the smear. Absence of bubbles constitutes a negative catalase test, indicating a probable streptococcus culture. The presence of bubbles indicates a positive catalase test which suggess a non streptococcal species is present. Confirmation would be discontinued. Growth in brain-heart infusion broth and bile broth medium containing 10% oxgall solution confirms the test for fecal streptococci.

Positive and negative controls would be run in the series of tests including filtration and confirmation.

PART A
BACTERIOLOGICAL EXAMINATION AND BIOCHEMICAL OXYGEN DEMAND

SECTION I: BACTERIOLOGICAL EXAMINATION

The methods followed are in Standard Methods for the Examination of Water and Wastewater, 16th Edition, 1985.

Total coliform counts were conducted according to procedure SM909A. The results are shown in Table 1. All organisms that produced a colony with a golden-green metallic sheen were considered to be coliforms. A representative number of typical colonies were transferred to tubes of lauryl tryptose broth and brilliant green lactose bile broth. Gas was formed in 48 hr. (35°C) confirming coliform presence. The positive and negative controls confirmed the medium employed detected total coliforms.

Standard Method 909C was employed to detect fecal coliforms. As few non-fecal coliforms are detected on m-FC medium due to the selective action of the elevated incubation temperature and the rosolic acid salt reagent further testing was not required to confirm the colonies that developed as fecal coliforms. Positive and negative controls run with the sample indicated that the M-FC medium could detect fecal coliforms. The test for fecal streptococci was stated as SM909C in Table 4 of ORF's price quotation (January 27th, 1986). This should read method SM909B.

A representative number of red and pink colonies were picked from the KF Streptococcus plates. The colonies were inoculated onto brain heart infusion agar slants. A loopful of growth from the 48 hr. brain heart infusion slants was transferred to a microscope slide and fresh 3% hydrogen peroxide was added to the smear. The absence of bubbles constituted a negative catalase test, indicating a probable streptococcus culture. In addition, growth from the brain heart infusion slant(s) was inoculated into brain heart infusion broth (45°C incubation) and bile broth (with 10% oxgall solution), (35°C incubation). All tubes showed growth, confirming the test for fecal streptococci. Positive and negative controls also confirmed that the media could detect fecal streptococci.

A total heterotrophic count (Standard Plate Count) was conducted according to Method SM907A. Tryptone glucose extract agar was employed using the pour plate method. Incubation was at 20°C for 7 days.

All counts were determined using a binocular stereoscopic microscope. Sterility of the media used was confirmed.

The results for these four biological parameters for sample 9925-0598 (received April 2nd, 1986) are 26 total coliforms per 100 mL of sample, 10 fecal coliforms per 100 mL of sample, 550 fecal streptococci per 100 mL of sample and 1.6×10^4 colony forming units per mL of sample.

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SECTION II - BIOCHEMICAL OXYGEN DEMAND

Reference: Standard Methods for the Examination of Water and Wastewater, 16th Edition, 1985. Method No's. 507 and 421B.

Immediately upon receipt, aliquots of sample were vigorously shaken to air saturate and poured into 300 mL capacity, water seal BOD bottles. Aliquots of less than 300 mL were diluted with nutrient and micro-organism enriched, aerated water.

The azide modification to the iodometric titration was used to determine the initial (immediate) dissolved oxygen of the dilution water "blank", "seed" (settled domestic raw sewage used to enrich with micro-organisms), "seeded" dilution water, glucose-glutamic acid check, and the sample.

Bottles of dilution water blanks, "seed", "seeded" dilution water, glucose-glutamic acid check, and sample in water sealed BOD bottles were placed in a light excluded incubator at 20 $\pm$ 1°C and dissolved oxygen determined after five days using the azide modification to the Winkler iodometric titration.

Biochemical Oxygen Demand (BOD) was determined, after correction for "seed" where appropriate, by difference from the initial Dissolved Oxygen (DO) content of the sample and the DO of the sample after five days.

QUALITY ASSURANCE

The dilution water blank had a BOD-5 day of less than 0.1 mg/L O_2. The DO uptake of the seeded dilution water was 0.75 mg/L O_2. The glucose-glutamic acid check resulted in an average BOD-5 day of 235 mg/L, which is in the "Standard Methods" acceptable range of 200 $\pm$ 37 mg/L BOD.

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